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THE UTILIZATION OF SUNFLOWER SEED OIL MEAL, WHEAT DISTILLERS' DRIED GRAINS AND RAPESEED OIL MEAL IN POULTRY RATIONS[1]

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A survey of the literature revealed little information concerning the possible use of sunflower seed oil meal, wheat distillers' dried grains, or rapeseed oil meal in poultry rations. However, Tabakoff (3) obtained satisfactory results when as much as 20% of sunflower seed oil meal was included in a ration fed to laying hens, while Fangauf and Haensel (1) reported success when 10% of rapeseed oil meal was fed to layers. Wheat distillers' dried grains has been used extensively in the feeding of several classes of livestock, especially dairy cattle, but has not been generally accepted as a poultry feed.

I. SUNFLOWER SEED OIL MEAL, WHEAT DISTILLERS' DRIED GRAINS, AND RAPESEED OIL MEAL IN STARTING RATIONS

These experiments were set up in an attempt to replace part or all of the meat meal in a good chick starting ration with sunflower seed oil meal, wheat distillers' dried grains and rapeseed oil meal. To check each of these products 8 groups of 34 day-old Barred Plymouth Rock chicks, of which 17 were males and 17 females, were used. All birds were wing banded and weighed at the commencement of the experiment and were subsequently weighed at weekly intervals for the 10-week period which constituted the growth trials.

Three separate hatches, at 3-day intervals, supplied the chicks for these trials. The chicks from the first hatch were used for the work on sunflower seed oil meal, those from the second for the work on wheat distillers' dried grains, and those from the third were used for the experiment on rapeseed oil meal. Birds which died during the first week of an experiment were replaced by "spares" from the same hatch. Mortality during the first week was not considered to be a result of the ration fed.

All groups were started in the same type of electrically heated battery brooders in an air conditioned building, the temperature of which was thermostatically maintained at approximately 80° F. At 5 weeks of age, all birds were moved to growing batteries where they were confined for the remaining 5 weeks.

The individual ration ingredients were analysed for protein and these data subsequently used in making up rations which contained approximately 18% protein. All three products under test were considered as vegetable protein concentrates and were included in the rations to replace

[1] A contribution from the Departments of Poultry Husbandry and Animal Nutrition. J. Walker and E. C. Roberts assisted with the project and a part of the work formed their undergraduate thesis in fulfilment of the requirements for the Degree of Bachelor of the Science of Agriculture (1943). This thesis was awarded the Canadian Feed Manufacturers' prize for the best thesis in Animal Nutrition in 1943.

successively larger amounts of meat meal on a protein equivalent (N × 6.25) basis. Since the supplements in question were all lower in protein content than the meat meal, it was necessary to use quantities of the supplements which were larger than the amounts of meat meal replaced in order that the protein content of the rations might be kept constant. At the same time, the amounts of ground barley were decreased accordingly.

The same basal mixture was used in testing each of the three supplements. This basal mixture which was used for each 100 pounds of ration is presented in Table 1.

TABLE 1.—BASAL MIXTURE

Ingredient	Weight
	lb.
Ground oat groats	18.0
Ground yellow corn	18.0
Ground wheat	18.0
Cereal grass	1.0
Dehydrated alfalfa	2.5
Buttermilk powder	10.0
Salt*	1.0
Steamed bone meal	1.0
Oyster shell	1.0
Grit (insoluble)	1.0
Cod liver oil†	0.25
Total	71.75

* Contained 0.02% KI and 2.0% $MnSO_4.4H_2O$.
† Contained 400 A.O.A.C. chick units of vitamin D and 3000 I.U. of vitamin A per gram.

Although 1 lb. each of bone meal, oyster shell and grit was supplied in the basal mixture, an additional *ad libitum* supply of each was given to all groups. Feed and fresh water were before the birds at all times. Records were kept of the total group consumption of feed, oyster shell, bone meal and grit.

(a) Sunflower Seed Oil Meal in Starting Rations

Table 2 shows the ration composition, mortality data and average live weight at 10 weeks of age for each group. The average weekly weights and gains are presented in Figure 1.

TABLE 2.—SUNFLOWER SEED OIL MEAL IN STARTING RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Basal (%)	71.75	71.75	71.75	71.75	71.75	71.75	71.75	71.75
Meat meal (%)	10.5	9.0	7.5	6.0	4.5	3.0	1.5	—
Ground barley (%)	17.75	17.25	16.75	16.25	15.75	15.25	14.75	14.2
Sunflower seed oil meal (%)	—	2.0	4.0	6.0	8.0	10.0	12.0	14.0
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mortality (total)	1	2	3	4	2	4	1	3
Weight at 10 Weeks (gm.)	949.2	966.7	1039.4	902.4	895.2	910.3	918.2	933.4

The 10-week old weight data were analysed for significance by the method of "weighted squares of means." This method, proposed by Yates (5) has been adapted for the interpretation of data from chick nutrition experiments by Titus and Hammond (4). Tests of significance

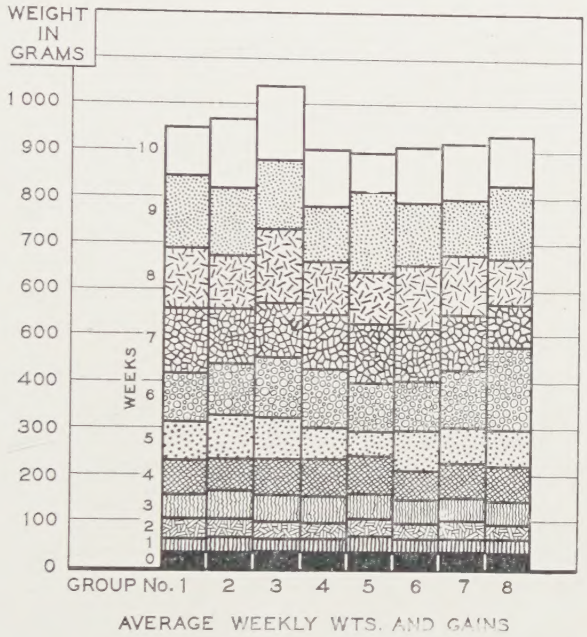

FIGURE 1. Average weekly weights and gains on sunflower seed oil meal in starting rations.

were made by means of the *F* test (Snedecor (2)). The *F* value for diet did not reach the 5% level, and it may be concluded, therefore, that the average weights at 10 weeks on the 8 diets were not significantly different.

The results indicate that under the conditions of this experiment, sunflower seed oil meal may be used to replace its protein equivalent of meat meal in amounts up to 14% of the ration, representing a complete substitution of the meat meal.

(b) Wheat Distillers' Dried Grains in Starting Rations

The wheat distillers' dried grains used in this experiment contained all of the outer coats of the wheat but did not contain the solubles. The procedure for the test with this feedstuff was the same as that for the sunflower seed oil meal. Since the protein content of wheat distillers' dried grains, however, is considerably lower than that of sunflower seed oil meal, the amounts of wheat distillers' dried grains required to replace meat meal on a protein equivalent basis were necessarily greater and the reductions in the amounts of barley correspondingly large.

Table 3 indicates the composition of the rations used in the wheat distillers' dried grains test, together with the total mortality and the average live weight at 10 weeks for each group.

TABLE 3.—WHEAT DISTILLERS' DRIED GRAINS IN STARTING RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Basal (%)	71.75	71.75	71.75	71.75	71.75	71.75	71.75	70.5
Meat meal (%)	10.5	9.0	7.5	6.0	4.5	3.0	1.5	—
Ground barley (%)	17.75	16.25	13.75	10.25	5.75	2.25	0.75	—
Wheat distillers' dried grains (%)	—	3.0	7.0	12.0	18.0	23.0	26.0	29.5
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mortality (total)	3	4	4	1	4	0	2	1
Weight at 10 weeks (gm.)	1001.0	871.8	874.6	969.4	921.6	861.2	880.5	879.7

It will be noted that the ration of group 1 in this experiment was identical with that of group 1 in the sunflower seed oil meal trial. However, as pointed out previously, the chicks for this experiment were from a different hatch, thus necessitating this apparent duplication. The average weekly weights and gains are shown in Figure 2.

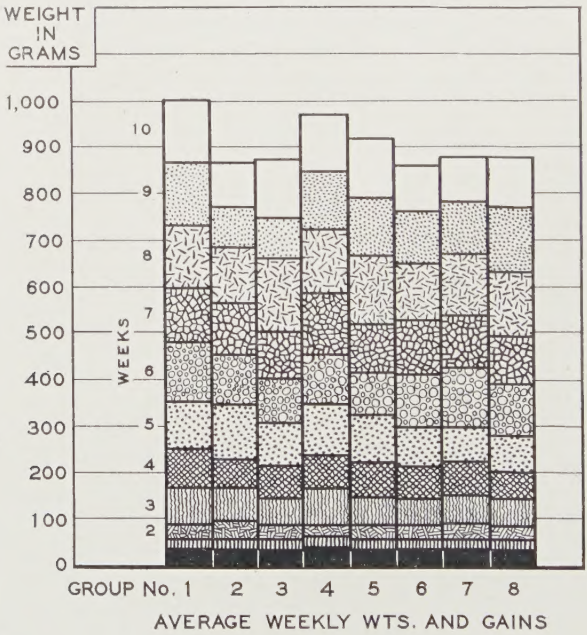

FIGURE 2. Average weekly weights and gains on wheat distillers' dried grain in starting rations.

As in the previous experiment an analysis was made on the 10-week weight data, but, in this case, the F value for diet exceeded the 5% point and it may be concluded that the weights were significantly different.

By application of the *t* test to the differences between the unweighted mean live weights of males and females on any two different diets, it was found that all groups except number 4 were significantly poorer than group 1 (the negative control group). There was no significant difference between groups 1 and 4. Since all groups excepting number 4 proved to be significantly poorer than the control, it would appear that wheat distillers' dried grains is not a complete substitute for any of the meat meal in this ration.

However, even in amounts up to 29.5% of the ration, wheat distillers' dried grains caused no mortality and the birds showed no untoward symptoms other than decreased growth. Therefore, if wheat distillers' dried grains is low in price as compared to other protein supplements or if no other more suitable vegetable protein concentrate is available, it can be used to replace at least part of the meat meal in such a ration as here employed without risk of harmful effects other than slightly decreased growth.

Other apparent disadvantages of wheat distillers' dried grains as a protein supplement for chick starting rations are its extreme bulkiness and its relatively low protein content.

(c) Rapeseed Oil Meal in Starting Rations

The procedure of this experiment was the same as that employed in parts (a) and (b). The composition of the rations, total mortality and average live weight at 10 weeks for each group are shown in Table 4. The basal mixture was the same as that used in the previous experiments. The average weekly weights and gains are shown in Figure 3.

TABLE 4.—RAPESEED OIL MEAL IN STARTING RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Basal (%)	71.75	71.75	71.75	71.75	71.75	71.75	71.75	71.75
Meat meal (%)	10.5	9.0	7.5	6.0	4.5	3.0	1.5	—
Ground barley (%)	17.75	17.25	15.75	14.25	12.75	11.25	9.75	8.25
Rapeseed oil meal (%)	—	2.0	5.0	8.0	11.0	14.0	17.0	20.0
Totals	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mortality (total)	0	1	1	1	1	3	2	8
Weight at 10 weeks (gm.)	957.9	932.5	897.2	924.4	926.2	954.2	898.5	792.9

The 10-week weight data were analysed as in parts (a) and (b).

The *F* value for diet exceeded the 5% level, therefore, the *t* test for the significance of difference between the unweighted mean live weights of males and females on any two different diets was applied. The results are shown in Table 5.

As indicated in Table 5, none of the groups fed rapeseed oil meal gave significantly better growth to 10 weeks than the control group.

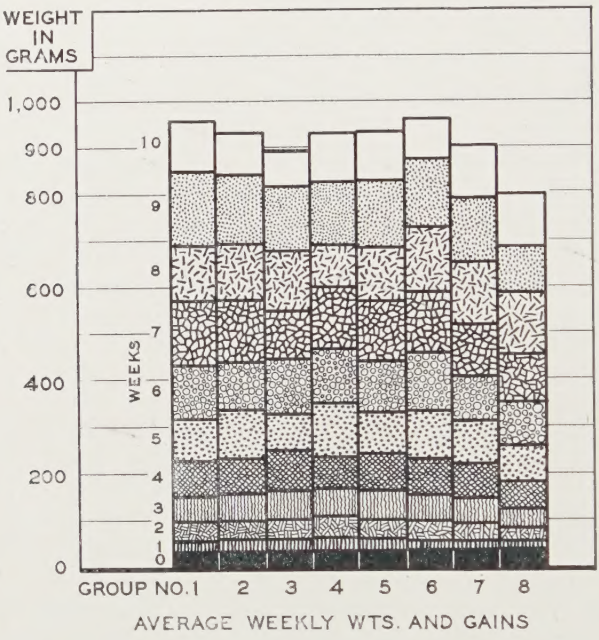

FIGURE 3. Average weekly weights and gains on rapeseed oil meal in starting rations.

As shown in Figure 3, groups 3, 4 and 5 grew quite satisfactorily up until the end of the fourth week. However, subsequent to this time, a "sour crop" condition developed in these groups, after which poorer gains

TABLE 5.—SIGNIFICANCE OF DIFFERENCE BETWEEN DIETS

Group No.	Significantly better than	Significantly poorer than
1	3, 4, 5, 7, 8	None
2	3, 7, 8	None
3	8	1, 2, 4, 5, 6
4	3, 7, 8	1
5	3, 7, 8	1
6	3, 7, 8	None
7	8	1, 2, 4, 5, 6
8	None	All

were registered. Since groups 6, 7 and 8 were fed rations containing rapeseed oil meal in higher concentrations than groups 3, 4 and 5, and since these birds did not develop the "sour crop" condition noted in the former groups, it may be assumed that the rapeseed oil meal was not responsible for the condition. Had this crop condition not arisen, it seems probable that the three groups thus affected would have given 10-week weights significantly equal to those of groups 1, 2 and 6.

When 17% of rapeseed oil meal was included in the ration (group 7), the growth during the early weeks of the experiment was somewhat reduced, and this reduction was even more noticeable when 20% rapeseed oil meal was used. However, the growth in both these groups was just as good as any of the others after the fifth week of age. This may indicate that when the birds have adapted their digestive systems to the handling of these larger amounts of rapeseed oil meal, they will make satisfactory gains.

When all the meat meal was replaced by rapeseed oil meal (group 8), there was a high mortality (Table 4). In addition, the surviving birds feathered slowly and unevenly and the feathers appeared dull and indistinctly barred.

It may be concluded, therefore, that, under the conditions of this experiment, rapeseed oil meal is a satisfactory substitute for meat meal in amounts up to 14% of the ration. When 17% of rapeseed oil meal is included, the growth during the early period of the bird's life is somewhat reduced and when 20% rapeseed oil meal is used to replace all of the meat meal, not only is there a reduction in growth during the early period of life but considerable mortality results.

II. SUNFLOWER SEED OIL MEAL AND WHEAT DISTILLERS' DRIED GRAINS IN LAYING AND BREEDING RATIONS

The experiment was planned to test the value of sunflower seed oil meal and wheat distillers' dried grains as protein supplements in a layer-breeder mash. Nine groups of 25 Barred Plymouth Rock pullets and 2 cockerels were used. The pullets and cockerels were all of the same age and breeding and were selected only for strong healthy appearance without standard disqualifications. In September, when the birds were beginning to lay, they were placed in pens which were 12 feet square and equipped with trap nests. Birds which died were replaced immediately by others of the same breeding and during the hatching season eggs laid by the replacements were not set until the birds had been in the pens for 10 days. The birds were started on the experimental rations during the last week of November, and production records were kept for a 6-month period, December 1 to May 31.

All eggs laid from February 1 to April 30, other than those which were cracked, were incubated. During the incubation season, the cockerels were rotated once a week in order to eliminate any chance of the males influencing the hatching results. The eggs were held for 3-day intervals and were set on the morning of the fourth day. The eggs were all incubated in the same 6,000-egg electric incubator and on the eighteenth day were transferred to an electric hatcher. During incubation, the eggs were candled three times—on the seventh day to remove the infertile eggs and early dead germs, and on the twelfth and eighteenth days to take out the later dead germs. All the eggs taken out were opened to check the accuracy of the candling and all the dead germs were classified according to the day they died. Notes were made on any abnormalities or malpositions. All unhatched eggs left on the trays after the completion of the hatch were also opened and classified.

The sunflower seed oil meal and wheat distillers' dried grains were considered as vegetable protein concentrates, and were included in the rations so as to replace part or all of the soybean oil meal and part of the meat and fish meals, on a protein equivalent (N × 6.25) basis. The mash was adjusted to a 19% protein level and, in order to keep the protein content of the rations constant, it was necessary, in addition to replacing the protein concentrates, to decrease the amount of ground barley in the mash as larger amounts of the supplements were included. Group 1 was used as a control.

The same basal mixture was employed in testing both supplements. This basal mixture which was used for each 100 pounds of mash is presented in Table 6.

TABLE 6.—BASAL MIXTURE

Ingredient	Weight
	lb.
Ground yellow corn	19.0
Ground wheat	5.0
Wheat bran	8.0
Wheat shorts	5.0
Ground whole oats	9.0
Rolled whole oats	9.0
Dehydrated alfalfa	4.0
Cereal grass	2.0
Dried buttermilk	5.0
Dried whey	2.5
Oyster shell	2.0
Salt*	1.0
Cod liver oil†	0.5
Total	72.0

* Contained 0.02% KI and 2.0% $MnSO_4.4H_2O$.
† Contained 400 A.O.A.C. chick units of vitamin D and 3000 I.U. of vitamin A per gram.

Besides receiving 2% of fine oyster shell in the mash, coarse oyster shell was fed *ad libitum* in a separate hopper as were also bone meal and grit. Mash was before the birds at all times and grain was fed every day before the birds went to roost on a per diem basis of 3.5 lb. per group. The grain mixture consisted of 1 part oats, 1 part corn, and 2 parts wheat.

(a) Sunflower Seed Oil Meal in Laying and Breeding Rations

The composition of the rations is shown in Table 7.

TABLE 7.—COMPOSITION OF RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
	%	%	%	%	%	%
Basal	72.0	72.0	72.0	72.0	72.0	72.0
Ground barley	12.0	12.0	12.0	11.5	11.25	11.5
Soybean oil meal	6.0	3.0	—	6.0	6.0	—
Sunflower seed oil meal	—	3.0	6.0	3.0	3.25	9.0
Meat meal	5.0	5.0	5.0	2.5	5.0	2.5
Fish meal	5.0	5.0	5.0	5.0	2.5	5.0
Totals	100.00	100.00	100.00	100.00	100.00	100.00

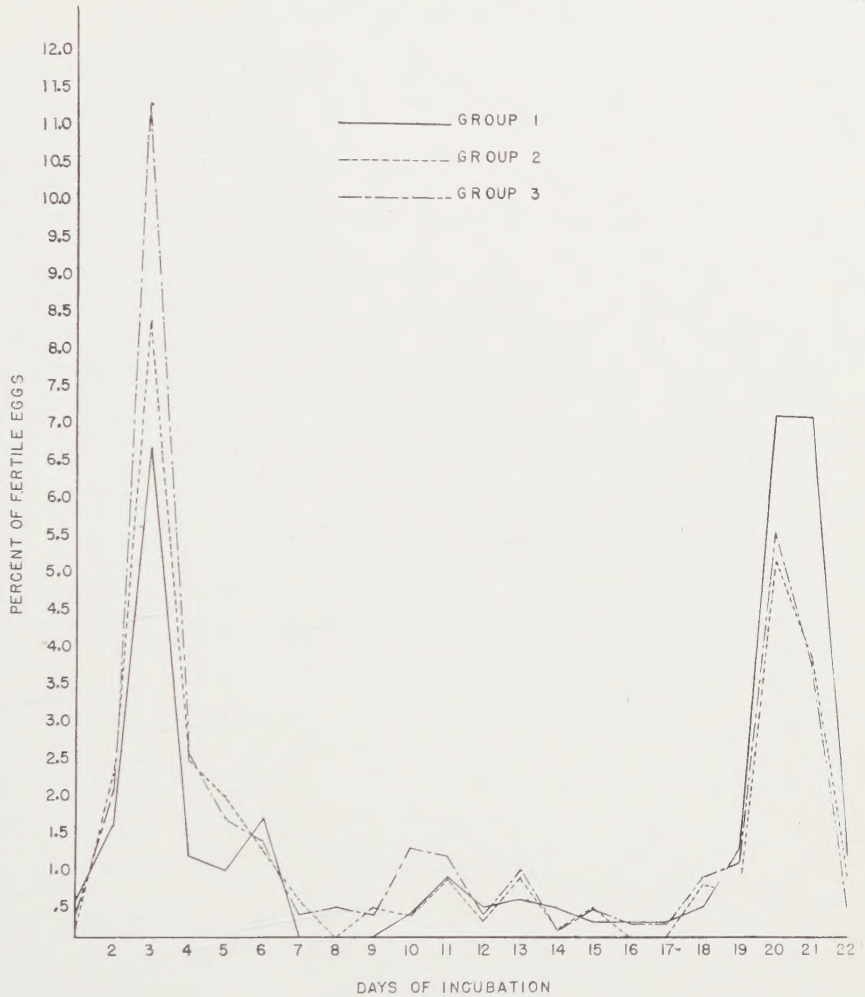

FIGURE 4. Distribution of embryonic mortality on sunflower seed oil meal in laying and breeding rations.

Figures 4 and 5 show the distribution of the embryonic mortality. Table 8 shows the egg production results for the 6-month period, and the hatchability results for the 3 months, February, March and April.

As shown in Table 8, all groups except number 4 showed approximately equivalent production. The production in group 4 was considerably lower than in any of the other groups. A study of the individual hen records revealed, however, that the group contained an unusually high proportion of birds with very low production records. Whereas none of the other groups contained more than 2 or 3 birds with a production below 25%, a level generally interpreted as indicating abnormality, group 4 contained 7 birds with productions ranging from 5 to 25%. The production of the remainder of the birds in the group was equally as good as that for any of the other groups. Hence it seems justifiable to assume that the low production figure (42%) for group 4 is not attributable to the ration.

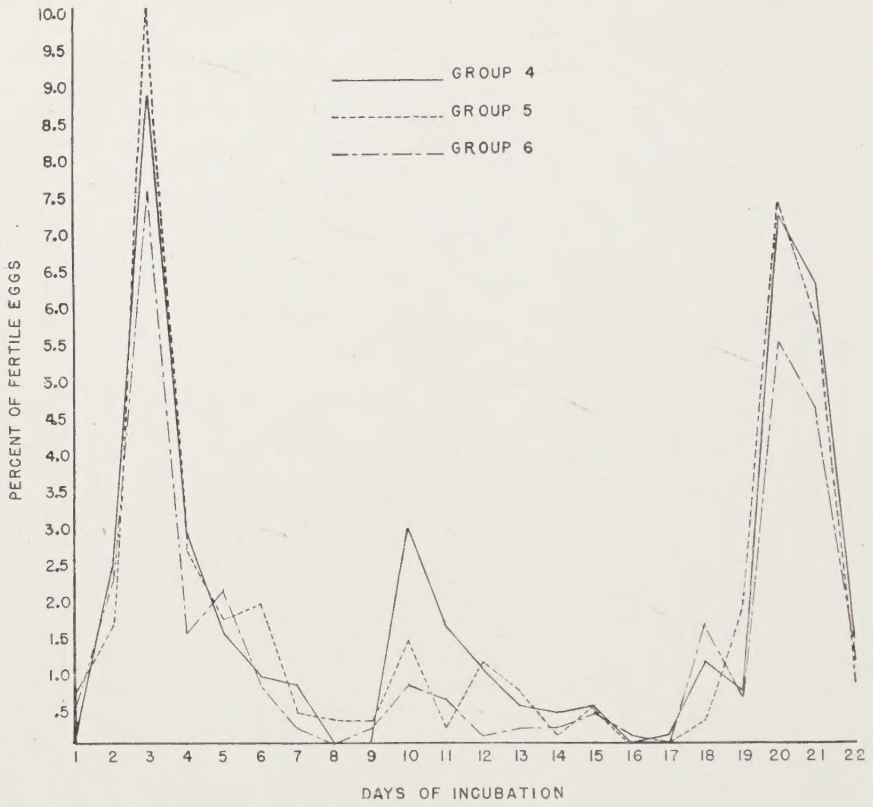

FIGURE 5. Distribution of embryonic mortality in sunflower seed oil meal in laying and breeding rations.

As shown in Table 8, there were some monthly variations in hatchability but the averages for the 3-month period did not differ markedly. All chicks appeared to be of good quality at hatching time regardless of the group from which they were hatched.

TABLE 8.—EFFECT OF SUNFLOWER SEED OIL MEAL ON EGG PRODUCTION AND HATCHABILITY

Group	Egg production Dec. 1/42 to May 31/43		Fertile Eggs set	Hatchability* Feb. 1/43 to Apr. 30, 1943			
				February	March	April	Average
	Total	%	Total	%	%	%	%
1	2456	54	1026	63.0	69.0	73.0	68.0
2	2691	59	1116	73.0	69.0	66.0	68.0
3	2421	53	1020	60.0	69.0	65.0	64.0
4	1937	42	874	57.0	59.0	63.0	59.0
5	2545	56	974	57.0	63.0	57.0	60.0
6	2510	55	814	68.0	71.0	66.0	69.0

* Based on fertile eggs set.

As shown in Figures 4 and 5, all groups had a high embryonic mortality on the third, twentieth and twenty-first days. A higher percentage of the third day mortality occurred during the winter months of February and March than in April. The mortality during the rest of the incubation period was comparatively low, except in the case of group 4 which shows an embryonic peak on the tenth and eleventh days. This peak is considerably smaller than the first and third week peaks, and the mortality here is to a large extent the result of a greater number of abnormal embryos occurring at this time. The abnormalities were for the most part comprised of oedematous and chondrodystrophic embryos. Approximately 50% of the embryos that died on or after the eighteenth day were found to be in malposition within the shell.

The results indicate that under the conditions of this experiment, sunflower seed oil meal may be used satisfactorily in the mash of laying and breeding birds to replace any one of the following: all or part of the soybean oil meal, half the meat meal, half the fish meal or finally, all the soybean oil meal plus half the meat meal.

(b) Wheat Distillers' Dried Grains in Laying and Breeding Rations

The composition of the rations is shown in Table 9.

TABLE 9.—COMPOSITION OF THE RATIONS

Ingredient	Group 1	Group 7	Group 8	Group 9
	%	%	%	%
Basal	72.0	72.0	72.0	72.0
Ground barley	12.0	9.5	5.5	—
Soybean oil meal	6.0	3.0	—	—
Wheat distillers' dried grains	—	5.5	12.5	20.0
Meat meal	5.0	5.0	5.0	4.0
Fish meal	5.0	5.0	5.0	4.0
Totals	100.00	100.00	100.00	100.00

Figure 6 shows the distribution of the embryonic mortality. Table 10 shows the egg production results for the 6-month experimental period and the hatchability results for the 3 months, February, March and April.

TABLE 10.—EFFECT OF WHEAT DISTILLERS' DRIED GRAINS ON EGG PRODUCTION AND HATCHABILITY

Group	Egg production Dec. 1/43 to May 31/43		Fertile eggs set	Hatchability* Feb. 1/43 to Apr. 30/43			
				February	March	April	Average
	Total	%	Total	%	%	%	%
1	2456	54	1026	63.0	69.0	73.0	68.0
7	2608	57	863	70.0	66.0	68.0	67.0
8	2441	53	914	74.0	71.0	64.0	69.0
9	2438	53	1151	71.0	70.0	69.0	70.0

* Based on fertile eggs set.

As shown in Table 10, there were only small differences in egg production between the groups receiving wheat distillers' dried grains and the control group 1. The hatchability results for the 3 months showed little variation, the difference in the average hatch between the highest and the lowest being only 3%. As in the case of sunflower seed oil meal, there was no apparent difference in the quality of the chicks at hatching time.

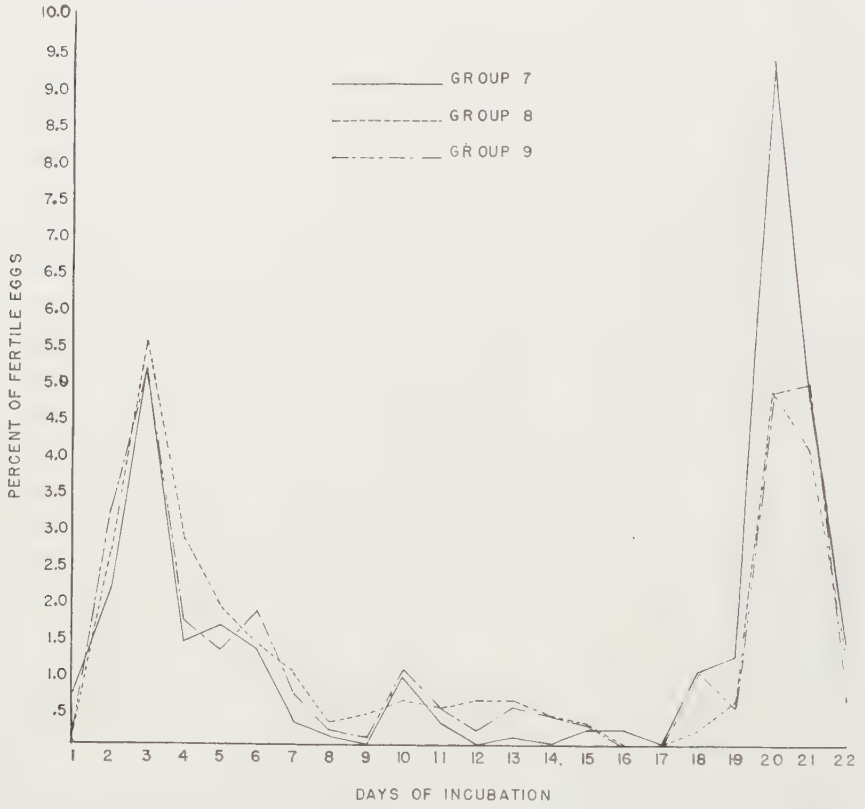

FIGURE 6. Distribution of embryonic mortality on wheat distillers' dried grains in laying and breeding rations.

As indicated in Figure 6, all groups had a high embryonic peak on the third, twentieth and twenty-first days, with comparatively little mortality at any other period of incubation. In comparison with the control group, the third-day peak for the groups receiving wheat distillers' dried grains was low, this being due to a lower mortality during the month of February. Group 7 had the highest embryonic peak during the third week because of a higher percentage of fully formed embryos which died previous to pipping the shell. Approximately 50% of the embryos which died on or after the eighteenth day were found to be in malposition within the shell.

The results indicate that under the conditions of this experiment, wheat distillers' dried grains may be used in the mash of laying and breeding birds to replace part or all of the soybean oil meal, or all of the soybean oil meal plus part of the meat and fish meals on a protein equivalent basis.

SUMMARY

An attempt has been made to substitute sunflower seed oil meal, wheat distillers' dried grains and rapeseed oil meal for meat meal in a ration fed to growing chicks. In addition, sunflower seed oil meal and wheat distillers' dried grains have been used to replace soybean oil meal, meat meal and fish meal in a layer-breeder mash.

From the results of these trials, it is apparent that sunflower seed oil meal can be used safely and satisfactorily to replace all of the meat meal in the chick starter ration here employed.

The egg production and hatchability results indicate that sunflower seed oil meal can adequately replace part or all of the soybean oil meal, or half of the meat meal, or half of the fish meal in the laying and breeding ration. It was found also that all of the soybean oil meal plus half of the meat meal could be replaced by sunflower seed oil meal in this ration without any serious decrease in egg production or hatchability.

Wheat distillers' dried grains, while not as suitable a protein concentrate as sunflower seed oil meal, produced no outstanding ill effects when included in the starter ration in amounts up to 29.5%. However, since growth appears to be somewhat retarded with the substitution of wheat distillers' dried grains for meat meal, it is recommended that this product be used in starting rations only if more suitable vegetable protein concentrates are not available, or if the cost is relatively lower than other protein feeds.

In the case of the layer-breeder mash, however, quite satisfactory results were obtained when wheat distillers' dried grains was used to replace all or part of the soybean oil meal, or all the soybean oil meal plus part of the fish and part of the meat meal. In this latter case, 20% of wheat distillers' dried grains was included in the mash.

Under the conditions of this experiment, rapeseed oil meal proved to be a satisfactory substitute for meat meal in amounts up to 14% of the chick starter used. When 20% of rapeseed oil meal was included in the ration to replace all the meat meal, however, considerable mortality and a reduction in the rate of growth during the early period of the birds' life resulted.

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AN ATTEMPT TO TRANSFER SOLID STEM FROM *TRITICUM DURUM* TO *T. VULGARE* BY HYBRIDIZATION[1]

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Solid-stemmed wheat varieties are more resistant to attacks of the western wheat-stem sawfly (*Cephus cinctus*) than are hollow-stemmed varieties, Kemp (6) and Farstad (3). Platt and Farstad (unpublished data) have found that among the solid-stemmed varieties, Golden Ball, a variety of *Triticum durum*, has been more resistant than the solid-stemmed varieties of *T. vulgare*, imported from New Zealand by Kemp (6) to this Station. Furthermore, Golden Ball has the ability to maintain its stem solidness and, consequently, its sawfly resistance under a wider range of environmental conditions than have the solid-stemmed varieties of *T. vulgare* Platt (10). It seemed desirable, therefore, to attempt to transfer the solid-stem character of Golden Ball to hollow-stemmed varieties of *T. vulgare* by hybridization. This paper summarizes the results that have been obtained.

That such a project was likely to be difficult, if not impossible, is evident from a survey of the literature. The situation appears to be this. According to Yamashita (13) there is a gene for hollowness in the C genom that is epistatic to the genes for solidness in the A and B genoms. He has labelled this gene O_D. Assuming the ordinary mechanism of meiosis in pentaploids in which the chromosomes of the C genom do not mate with those of the A or B genoms, it would seem impossible to replace O_D with a gene for solidness by hybridization. The only possibility of accomplishing such a task would be through segmental interchange between semi-homologous chromosomes from different genoms. There is considerable evidence that such rearrangements do occur, according to Huskins (5) and Love (7). The chances of obtaining desirable recombinations by such a mechanism are, of course, very small.

As this project was begun in 1937, the year Yamashita's paper was published, and as his paper was not available until some time later, it was deemed advisable to carry the project in a modified form to its conclusion. The results might be expected to substantiate or modify his interesting hypothesis.

The literature on the inheritance of solid stem and a good discussion on the possibilities of transferring it from durum to vulgare wheats has been given by Putnam (12).

MATERIALS AND METHODS

The two crosses studied were R.L. 1097 (*T. vulgare*) × Golden Ball (*T. durum*) and Regent (*T. vulgare*) × Golden Ball. Regent and R.L. 1097 were produced by the Dominion Rust Research Laboratory from the cross

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H-44 × Reward. Golden Ball was imported into America from South Africa. The contrasting parental characteristics studied in this investigation are listed in Table 1.

TABLE 1.—CHARACTERS OF PARENTAL VARIETIES STUDIED

Character studied	Variety		
	Golden Ball	R.L. 1097	Regent
Stem solidness	Solid	Hollow	Hollow
Spike density	Dense	Lax	Lax
Seed length	Long	Short	—
Seed colour	Amber	Red	—
Brush length (seed)	Short	Long	—
Stem rust reaction	Mod. suscep.	Resistant	—
Leaf rust reaction	Resistant	Resistant	—
Bunt reaction	Highly resistant	Mod. suscep.	—
Chromosome no.	$n = 14$	$n = 21$	$n = 21$

The first cross was made in the greenhouse of the Cereal Division, Central Experimental Farm, Ottawa, during the winter of 1937–38, the second at Swift Current in the spring of 1939. The F_1 and F_2 were space planted in the field at Swift Current and later generations were grown in progeny rows, each line being sown in a 10-foot row on dry land and in a 5-foot row on irrigated land.

The F_2 plants of the cross R.L. 1097 × Golden Ball were classified for stem solidness, spike density, seed length, seed colour and brush length. Stem solidness was noted by splitting a main culm from end to end and recording it as solid, semi-solid or hollow. Spike density was recorded as the number of millimetres occupied by 5 rachis internodes near the middle of the spike. The other characters were classified by inspection into either of the parental classes.

Except for selected lines, only general observations were made on the F_3 and later generations.

Stem and leaf rust readings were made on certain F_7 lines by Dr. R. F. Peterson at the Dominion Rust Research Laboratory, Winnipeg. The bunt reaction of certain F_3 and F_7 lines was determined by inoculating seed with a composite collection of chlamydospores and noting the percentage of plants infected in the case of the F_4 material and the percentage of spikes infected in the case of the F_7 material. In the former, approximately 35 plants of each lines were examined and in the latter, 400 spikes of each line.

In determining chromosome numbers, the young spikes were fixed in 3 : 1 absolute alcohol and glacial acetic acid for 24 hours. They were then put through the following series of alcohols, changing at 24-hour intervals: absolute, absolute, 95%, 95%, 80%, and 70%. The material was stored in 70% alcohol. The microsporocytes were stained with iron-aceto-carmine and examined at diakinesis, metaphase and early anaphase of the first reduction division. From 1 to 5 plants were examined in each of the 46 F_7 lines studied.

Selection was carried out in F_2 for plants, and in F_3 and later generations for lines, having various of the vulgare characters listed in Table 1 combined with stem-solidness. The vulgare characters were used as convenient indicators of vulgare genotype although characters such as brush length have no value in themselves.

RESULTS

No attempt was made to study the mode of inheritance of the characters examined. However, the numbers of plants occurring in the various phenotypes in the F_2 are presented in Table 2. It was noted that plants classified as solid-stemmed in the F_2 were, with a few exceptions, solid in the F_3. These exceptions will be referred to later and were from plants having an unusual combination of characters. Those F_2 plants with amber seeds also produced F_3 lines having this characteristic. All other phenotypes segregated in the F_3.

TABLE 2.—THE BREEDING BEHAVIOUR OF R.L. 1097 × GOLDEN BALL FOR SEVERAL CHARACTERS

Character	F_2	
	Phenotype	No. of individuals
Stem solidness	Solid	336
	Semi-solid	1489
	Hollow	1231
	Total*	3056
Seed length	Long	1877
	Short	1086
	Total	2963
Seed colour	Red	2315
	Amber	599
	Total	2914
Brush length	Long	1295
	Short	1676
	Total	2971

* Variations in totals due to inability to classify certain plants owing to sterility, shrunken seeds, etc.

Results from the tests of independence or association between solid stem and the other characters studied are presented in Table 3. The association between solid stem and dense spike was very high. While 25 F_2 plants were classified as having solid stems and lax spikes, no F_3 lines having this recombination were obtained. Four of the 25 plants were completely sterile. Seed from the balance was sown in F_3 lines. Nine of these were homozygous for dense spike and had evidently been wrongly

classified in the F_2. These plants were noted to have been severely attacked by common root rot in the F_2 and it is possible that the presence of this disease affected the expression of spike density. Similar effects due to bunt have been noted by Aamodt *et al.* (1). Eight of the F_3 lines segregated into hollow-stemmed lax-spike and solid-stemmed dense-spiked plants. These were the exceptional lines referred to above. Many plants in these lines were sterile. One line bred true for solid stem and lax spike but was sterile and two lines failed to germinate.

TABLE 3.—X^2 TEST OF INDEPENDENCE AND ASSOCIATION BETWEEN STEM-SOLIDNESS AND OTHER CHARACTERS IN THE F_2 OF THE CROSS R.L. 1097 × GOLDEN BALL

Stem solidness and	X^2	P lies between
Spike density	172.50	>.01
Seed length	1.94	.30 and .50
Seed colour	8.44	.01 and .02
Brush length	7.24	.02 and .05

While spike density is of no economic significance, results from similar crosses (2) have shown that the complete durum condition of spike density never appeared in 21-chromosome segregates. Therefore, the complete association between solid stem and spike density indicated that it would be impossible to obtain solid-stemmed lines with a chromosome number of 21.

Stem solidness was also found to be associated with amber seed colour and short brush but in both cases substantial numbers of the desired recombinations were obtained in the F_2 and later generations.

In the F_3 and later generations, solid-stemmed lines were selected that had vulgare-like seed characters. Eventually, 46 F_7 lines were obtained that had solid stems, dense spikes and vulgare-like seeds. None of the lines had seeds entirely vulgare-like but they were similar to the vulgare type in colour and brush length and were somewhat similar in length and shape. While these lines were entirely fertile, they lacked vigour. In comparative trials, the best line yielded less than either parent.

The reaction of some of these lines to certain diseases is presented in Table 4. No difficulty was experienced in combining the stem rust resistance of R.L. 1097 with the solid stem of Golden Ball. Three out of the 9 solid-stemmed lines tested were as resistant as the resistant parent. Both parents were resistant to leaf rust and no evidence of susceptibility was found in the 9 F_7 lines tested at Winnipeg nor in the 184 F_4 lines exposed to a natural leaf rust epidemic at Swift Current. The bunt reaction of the F_7 lines tested showed that they were as resistant or almost as resistant as the resistant parent. This would indicate an association between solid stem and bunt resistance. Further evidence in support of this is supplied by results from the test of 184 solid-stemmed F_4 lines. Only 7 of these were as susceptible as the susceptible parent, whereas 99 were as resistant as the resistant parent.

TABLE 4.—REACTION TO CERTAIN DISEASES OF F_7 LINES FROM THE CROSS R.L. 1097 × GOLDEN BALL

Hybrid No.	Stem rust	Leaf rust	Bunt infection
			%
H-41-143	Seg.*	R	3.0
-144	R	R	0.0
-145	MR	R	2.5
-146	R	R	5.0
-147	MS	R	1.5
-148	Seg.	R	1.5
-149	Seg.	R	2.0
-150	R	R	4.0
Golden Ball	MS	R	1.3
R.L. 1097	R	R	14.0

* The reactions designated by the symbols are as follows:
R Resistant
MR Moderately resistant
MS Moderately susceptible
Seg. Segregating.

When examined cytologically, all of the 46 F_7 lines were found to have a haploid chromosome number of 14. Behaviour in all cases, except one, appeared to be regular.

From the cross Regent × Golden Ball, an F_2 population of at least 25,000 plants was produced. All plants having lax spikes were selected and examined for solidness. Fourteen plants were found that had solid stems and lax spikes. Again, however, due to segregation and sterility, no F_3 lines were obtained that had this recombination of characters.

DISCUSSION

The solid-stemmed derivatives from the two crosses were preponderantly durum-like in appearance but through rigorous selection solid-stemmed derivatives were obtained that had various vulgare characteristics. The seed samples of many lines were much more vulgare-like than they were durum-like and certain of these exhibited the stem rust resistance of the vulgare parent. All, however, had dense spikes and a haploid chromosome number of 14. The vulgare characteristics that were combined with solid stem must, therefore, have been determined by genes located in the A or B genom or else by genes from the C genom incorporated in the A or B genom through translocation.

The failure to obtain solid-stemmed vulgare segregates lends support to Yamashita's hypothesis (13) that there exists a gene O_D for hollowness in the C genom that is epistatic to all other genes for solidness. Nevertheless, solid-stemmed varieties of *T. vulgare* do exist. Dr. Frankel of the Wheat Research Institute, Christchurch, New Zealand, states[3] "Solid stemmed wheats of *Triticum vulgare* are common in the Western Mediterranean countries, viz., Spain, Portugal, Algiers, Tunis and Morocco." Certain of these wheats obtained from these countries by Dr. Frankel and later obtained from him by this Station, have been studied for some years,

[3]Personal Communication.

Platt (10) and Platt *et al.* (11). The type of solidness exhibited by these varieties differs in two respects from that of Golden Ball. The vulgare solidness is more easily modified by environmental conditions and, under conditions that do not allow for maximum expression of solidness, they show hollowness just below the spike, whereas the durums are invariably solid at this point and show hollowness in one of the lower internodes. How such solid stemmed vulgare wheats originated cannot be stated at the present time. If they are derivatives from crosses between *T. vulgare* and *T. durum* or *T. turgidum*, then segmental interchanges between semi-homologous chromosomes must have taken place, in view of the results obtained by Yamashita and those obtained in the present investigation.

Despite their somewhat lower sawfly resistance, these solid-stemmed vulgare wheats offer much more promise as a source of resistance to this insect than does Golden Ball in breeding programs designed to produce agronomically desirable, sawfly resistant, vulgare wheats. In fact, it appears impracticable to attempt to transfer the solid-stem character and consequently the sawfly resistance of Golden Ball to vulgare wheats by hybridization. This is in marked contrast to the situation that exists with stem rust reaction where the durum resistance can be transferred to vulgare types without undue difficulty, Hayes *et al.* (4) and Peterson and Love (8).

SUMMARY

Crosses were made between Golden Ball, a solid-stemmed variety of *T. durum* ($n = 14$), and R.L. 1097 and Regent, hollow-stemmed varieties of *T. vulgare* ($n = 21$). In the former cross some 3,000, and in the latter some 25,000 F_2 plants were studied. Derivatives were found that had the solid-stemmed character of Golden Ball combined with certain seed characters and disease reactions of *T. vulgare*. However, all these lines had a haploid chromosome number of 14. It is concluded that it is not practicable to attempt to transfer the solid-stem character from *T. durum* to *T. vulgare* by hybridization.

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BROWN ROT AND OTHER FUNGAL WASTAGE IN HARVESTED PEACHES[1]

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In the five seasons which have elapsed since the first report (3) on brown rot investigations at the St. Catharines laboratory, the Niagara peach industry has twice been confronted with serious outbreaks of brown rot, once in 1940 and again in 1942. In the remaining three seasons brown rot has not been commonly regarded as serious, nevertheless, it has caused wastage in the packs under observation, and presumably in commercial packs also. In view of the current interest in the subject, it is considered advisable to make available the additional information accumulated since 1938. The present paper deals with the comparative incidence of brown rot and other rots in harvested fruit, as affected by various spray schedules, by refrigeration for different periods, and by other factors, during the years 1938 to 1942, inclusive. Some of the data were derived from experiments designed to determine the relative efficiency of different spray materials and some from experiments designed primarily as storage trials, carried on in co-operation with the Fruit and Vegetables Division of the Dominion Marketing Service.

The basic spray program followed were the "3-spray" and "4-spray" schedules, the former ending with an application 2 or 3 weeks before harvest, and the latter with a pre-pick spray just before harvest. On two occasions a 1-spray schedule, at harvest or 3 weeks before, was also used. The complete list of schedules and materials is given in Table 1, but not all of these materials were used every year.

Table 1.—Peach spray schedules

Application		Materials used					
3-spray schedule	Pre-blossom shucks	Kolo-form	Kolo-fog*	Bartlett's Standard Wettable	Lime-Sulphur 1-50	C.O.C.S.	Lime-Sulphur 1-50
	Shucks	Kolo-form	Kolo-fog	Bartlett's Standard Wettable Sulphur with lead arsenate, zinc sulphate and lime		Aero Sulphur	None
4-spray schedule	3 weeks before harvest	Kolo-form	Kolo-fog	Bartlett's Standard Wettable Sulphur		Aero	Sulforon
	Pre-pick	Kolo-pick or Dust	Kolo-pick or Kolo pre-pick	Bartlett's pre-pick or Dust	Ferrox Flotation Sulphur	Aero	Sulforon

* Or Kolo-fog extra.

[1] Contribution No. 752 from the Division of Botany, Science Service, Department of Agriculture, Ottawa Canada.

[2] Plant Pathologist.

The peaches for the spray trials were wrapped in tissue and packed in open lugs in 1938-39, but from 1940 on they were packed without wrapping. The peaches for the storage trials were packed each year unwrapped in open lugs. Since the quantities of fruit placed in the cold room at any one time were relatively small, cooling took place much more rapidly than it would in commercial car-loadings in iced cars, without pre-cooling. In most cases, the experimental lots reached the temperature of the store overnight. While the fruit used for this purpose was obtained only from sprayed blocks, the peaches from the different blocks were not kept separate. In each experiment an attempt was made to select fruit of fairly uniform ripeness using ground-colour as a guide. The riper and greener fruit were either culled out or made up into separate packs and followed through separately. As no artificial inoculations were made, any infections were the result of natural dissemination of inoculum, and in this respect the packs were essentially similar to commercial ones.

The various lots were examined at intervals and at each examination rots were classified as incipient, brown rot, Rhizopus or other rots, then counted and discarded. Fruits classified as having incipient rots were usable, having only small spots up to about one-half inch in diameter. The incipient rots were disregarded in the count for the day on which they were observed but were counted in with the brown rot of the next examination, unless obviously caused by *Rhizopus nigricans*, in which case they were counted with the Rhizopus rots for the day. Fruits attacked by brown rot and overrun by Rhizopus were counted as having brown rot. The other rots were caused by miscellaneous fungi, including *Penicillium* spp., *Alternaria* spp. and *Cladosporium* spp. Wastage from rots of this type is not of commercial importance as it usually occurs only after the peaches have been held until they are no longer edible.

Experiments in 1938

The regular storage trials with the varieties, Rochester, Vedette, Valiant and Elberta, in which the storage periods ranged from 6 to 16 days at 45° F. and from 10 to 28 days at 33° F., were supplemented by storage trials conducted in connection with the spray trials with Rochester and Elberta. In the supplementary tests with the Rochester variety triplicate packs were made from each plot of the spray experiment. One pack from each plot was held at room temperature, one for 5 days at 45° F. and one for 1 day at room temperature and 4 days at 45° F., to determine the effects of delayed cooling. In the corresponding experiment with Elberta, the storage periods were 8 and 7 days at 45° F., with immediate storage and 1-day delay, respectively, except in the case of two plots which were picked 1 day earlier and in consequence had 1 and 2 days delays. The trends in the Elberta trials only are given (Figures 1 and 2) but they illustrate the behaviour of the other varieties under similar conditions. Several points of interest may be noted.

(1) Successive new infection centres continued to appear during the time the fruit was held at room temperature, indicating that the spore populations on different individual fruits did not germinate all at one time. It is probable that each fruit had its own spore load at picking time, as the

greater rate of incidence of rots after the sixteenth day in the unwrapped peaches held 9 days at 45° F. than in the comparable wrapped fruit of the spray trials suggests that the transfer of spores from the earlier affected areas to sound fruits was reduced to a minimum by wrapping.

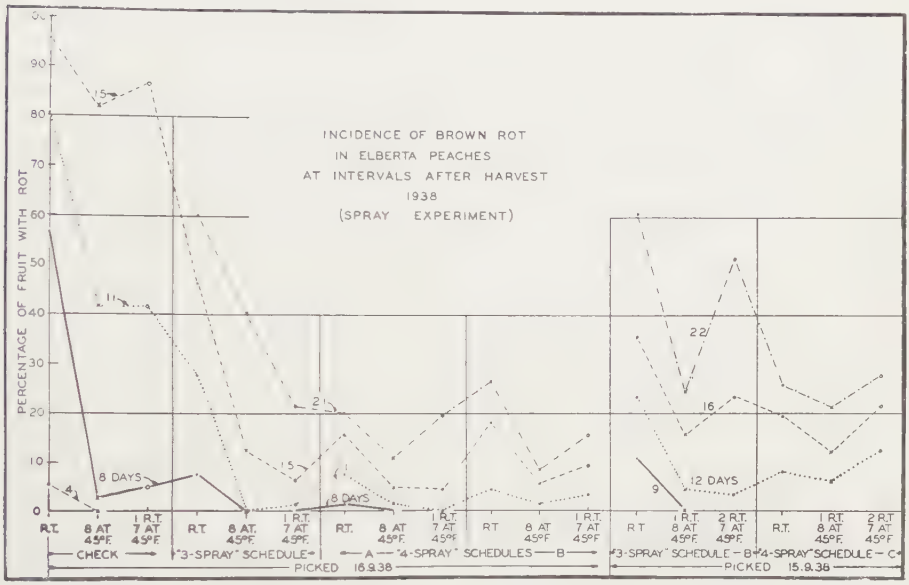

FIGURE 1. Incidence of brown rot in 1938 in Elberta peaches held at room temperature and after storage at 45° F. for 7 or 8 days, with no delay or with delays of 1 or 2 days at room temperature before cooling. In all figures, the numeral above each curve signifies the number of days after picking. The points in any one curve indicate the cumulative incidence of rot in the various lots examined on a given day.

(2) Little or no rot developed in sprayed peaches during the first 19 days of storage at 45° F. or the first 10 weeks at 33° F. The advantage

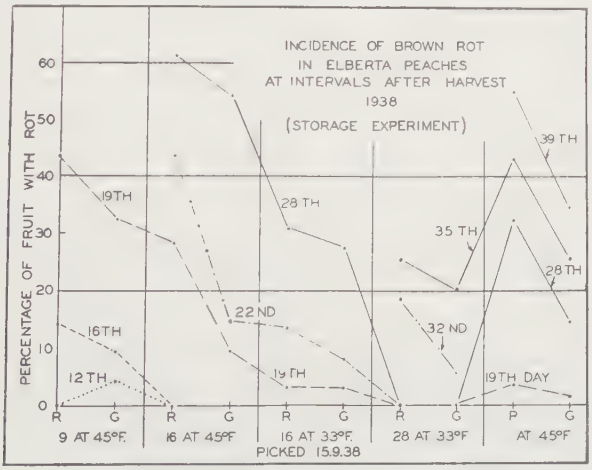

FIGURE 2. Incidence of brown rot in 1938 in Elberta peaches during storage at 45° F. and at room temperature after 9 or 16 days storage at 45° F. and after 16 or 28 days storage at 33° F. R. and G. represent riper and greener grades, respectively.

of the lower storage temperature in the control of brown rot was also reflected in the fact that the *greener* lots held 16 days at 45° F. showed a higher percentage of rot at successive examinations than did the *riper* lots held 16 days at 33° F. Furthermore the incidence of brown rot was about the same after 22 days of continuous storage at 45° F. as after 16 days at 33° F. and 6 days at room temperature.

(3) Comparison of the data for 9 and 16 days' storage at 45° F. and 16 and 28 days' storage at 33° F. suggests that the rate of incidence of brown rot after the return of the peaches to room temperature tends to be increased by prolonging the storage period at either low temperature.

(4) After removal from refrigeration, rot infections usually made their appearance sooner in the lots which were held 1 or 2 days before cooling than in those cooled on the day of picking.

(5) Wastage caused by *Rhizopus nigricans*, which is not shown in the figures, varied in importance in the different packs but was not serious in any lot during the first 2 weeks after harvest. This trouble did not develop in cold store. There was no evidence that it could be controlled by spraying. Once started it spread rapidly from fruit to fruit forming "nests" of decay.

TABLE 2.—EFFECTIVENESS OF SPRAY SCHEDULES IN THE CONTROL OF BROWN ROT AT ROOM TEMPERATURE IN 1938

Variety	"3-spray" schedules					"4-spray" schedules				
	Last spray	Rainfall		Control indices*		Last spray	Rainfall		Control indices	
		Time†	Amount	1st week‡	2nd week‡		Time	Amount	1st week	2nd week
			inches					inches		
Rochester	14†	11 6–7 1	.44 2.88 .17	68–87	80	4	1	.17	65-89	78-93
Elberta	22	13 9 5 4 2 1	.07 .71 .07 .12 .27 .07	80–86	52–57	6	5 4 2 1	.07 .12 .27 .07	97–100	78–84

* The control index, or reduction in incidence as result of treatment was calculated from the formula $C = 100 \frac{(c-s)}{c}$ where C = control index; c = percentage of rot in unsprayed and s in sprayed lots. † Time in days *before* harvest. ‡ *After* harvest.

In 1938 because of better weather at harvest the incidence of brown rot was considerably lower in Rochester than in Elberta. The various spray materials and schedules gave very good control (Table 2) during the first two weeks after picking. The falling off in the control indices for the "3-spray" schedule during the second week of the Elberta experiment was probably due to the series of showers just before harvest as well as to the longer time between spraying and picking.

Experiments in 1939

Data for the spray and storage trials in 1939 are given in Table 3 and Figure 3. The Rochester variety suffered more severely from brown rot than the other varieties in 1939. On the whole the spray programs were considerably less effective than in 1938. The longer time between the last spray of the "3-spray" schedule and harvest and the frequent heavy showers in the interval probably account for this.

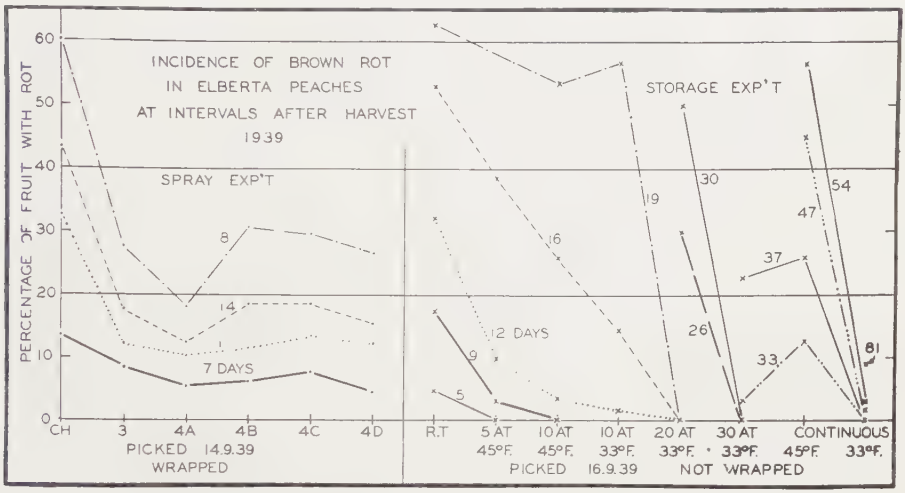

FIGURE 3. Incidence of brown rot in 1939 in Elberta peaches. In the spray experiment 3 indicates the "3-spray" schedule and 4A, 4B, 4C, 4D, different "4-spray" schedules. In the storage experiment, the storage periods are 5 to 10 days and continuous storage at 45° F. and 10, 20 and 30 days and continuous storage at 33° F.

TABLE 3.—EFFECTIVENESS OF SPRAY SCHEDULES IN THE CONTROL OF BROWN ROT AT ROOM TEMPERATURE IN 1939

Variety	"3-spray" schedules					"4-spray" schedules				
	Last spray	Rainfall		Control indices		Last spray	Rainfall		Control indices	
		Time*	Amount	1st week†	2nd week		Time	Amount	1st week	2nd week
			inches					inches		
Rochester	21*	20	.22	35.0	16.9	4	4	.08	82–91	60–80
		14	1.81				3	.17		
		10	1.08				1	.30		
		3–4	.15							
		1	.30							
Elberta	26	25–26	.15	38.0	59.0	5	5	.02	43–59	57–71
		23	.30				4	.47		
		9–10	.40				2	.20		
		7	.30							
		4–5	.49							
		2	.20							

* Time in days before harvest. † After harvest.

The results of the 1939 storage experiments in most respects resemble those of 1938. Notable exceptions, however, were observed in the Elberta lot held 10 days at 33° F., in which more rot developed between the sixteenth and nineteenth days, than in the comparable lot from 45° F., and in the Rochester and Vedette lots held 21 days at 33° F. in which the incidence of brown rot was exceptionally high. Brown rot also appeared during continuous storage at both low temperatures earlier than in 1938.

Comparison of the rates of incidence in sprayed peaches at room temperature suggests that the later pick used for storage tests was more subject to brown rot than the earlier one used for the spray tests. That this was due more to the greater exposure to contamination of the unwrapped fruit of the storage trials than to inherent difference in susceptibility is supported by the evidence from an earlier pack used for storage trials. The data presented in Figure 3 are for the second storage run, the first being picked 5 days earlier. The incidence of brown rot in these two storage experiments showed that only a slight increase in the susceptibility of Elberta peaches occurred in the interval between the two runs. Strikingly similar results were obtained in similar trials with the Rochester variety.

Again Rhizopus infections did not become serious until the second or third week after harvest and then only in lots at or returned to room temperature.

Experiments in 1940

Weather conditions generally were very favourable for a buildup of brown-rot inoculum during the summer of 1940, so that peaches even when picked under apparently satisfactory conditions quickly developed a high percentage of wastage (Figures 4 and 5). Under less favourable harvesting conditions, the losses from brown rot were immediate and severe.

The spray experiments show very clearly (Table 4) that while the "3-spray" schedule was in itself of little value in controlling brown rot in a season when the disease was difficult to hold in check, it proved its worth when used in conjunction with the pre-pick spray. In this regard, the experiment with Elberta was particularly instructive, since the pre-pick spray as a single application was only 36.3% efficient while the same material as part of the complete "4-spray" schedule was 62% efficient. In both the Rochester and Elberta spray experiments, there was a decided loss in the efficiency of the "4-spray" program during the second week after harvest. While the long lapse of time between the two last sprays of the schedule for Elberta was undoubtedly a contributing factor, the Rochester experiment (Table 4), in which the sprays were more normally timed, suggests that a considerable part of this loss in efficiency could be attributed to the fact that none of the peaches were wrapped in 1940. In this connection it should be noted that, in contrast with 1939 experience, there was little difference in the incidence of rot between the Elberta peaches held at room temperature for the storage trial and those receiving the "4-spray" schedule in the spray trial. In the experiments with the Rochester variety, the storage lot at room temperature behaved much the same as the "3-spray" lot in the spray tests.

TABLE 4.—EFFECTIVENESS OF SPRAY SCHEDULES IN THE CONTROL OF BROWN ROT AT ROOM TEMPERATURE IN 1940

Variety	"3-spray" schedule					"4-spray" schedule					Pre-pick only	
	Last spray	Rainfall		Control indices		Last spray	Rainfall		Control indices		Control indices	
		Time*	Amount	1st week†	2nd week†		Time	Amount	1st week	2nd week	1st week	2nd week
			inches					inches				
Rochester	29*	25–26	1.16	9.0	3.7	2	1	.30	40–65	18–43	—	—
		18	.20				0	.05				
		12	.65									
		9	.04									
		5	.09									
		3	.03									
		1	.30									
		0	.05									
Elberta	47	18–44	2.52	—	—	2	0	0	60–62	15–17.5	36.3	5.3
		17	.47									
		3	.62									

* Days before harvest. † After harvest.

Although in the storage trials (Figures 4 and 5) rots tended, both during and after refrigeration, to develop earlier than in other years, the relations between the various treatments followed fairly well the pattern

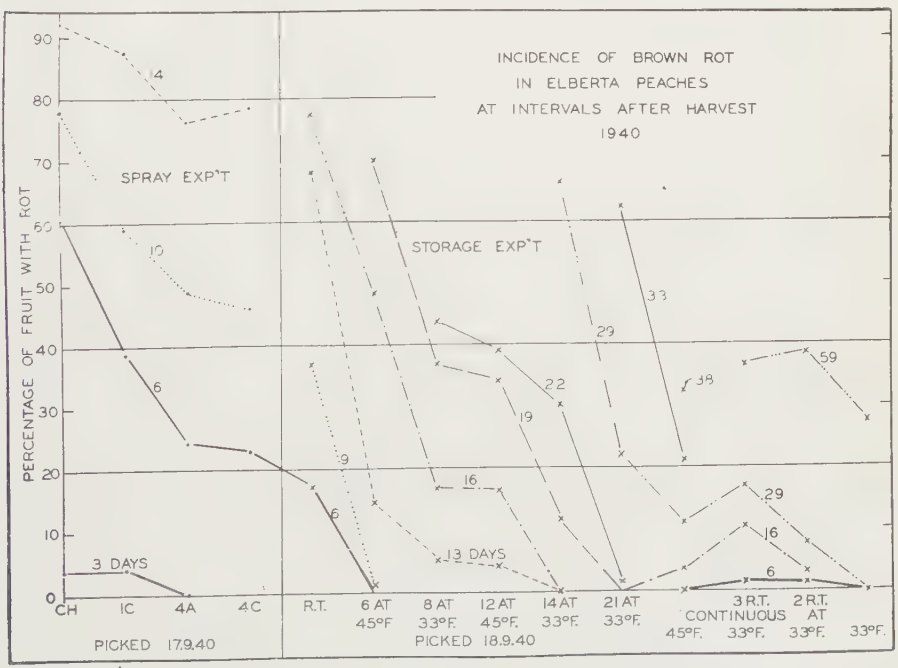

FIGURE 4. Incidence of brown rot in 1940 in Elberta peaches. 1C indicates pre-pick spray only and 4A and 4C, the "4-spray" schedules. Storage periods are 6 and 12 days at 45° F. and 14 and 21 days at 33° F. 3R.T. and 2R.T. signify 3 and 2 day delays at room temperature before storing at 33° F.

already outlined. Some lots of both Carmen and Elberta varieties were held 1 to 3 days at room temperature before being subjected to continuous refrigeration at 33° F. With both varieties the effects of delayed cooling on the onset of brown rot were noticeable during the first week or so of storage but were much more striking in the Carmen tests, partly because of higher temperature and humidity during the delay period and partly because of hail marks which were also to some degree responsible for the generally high incidence of brown rot in that variety. The first wave of rot in the lots cooled 3 days after picking were obviously the result of infections occurring early in the holding period at room temperature. Infections initiated towards the end of the 3-day delay or during the 1-day

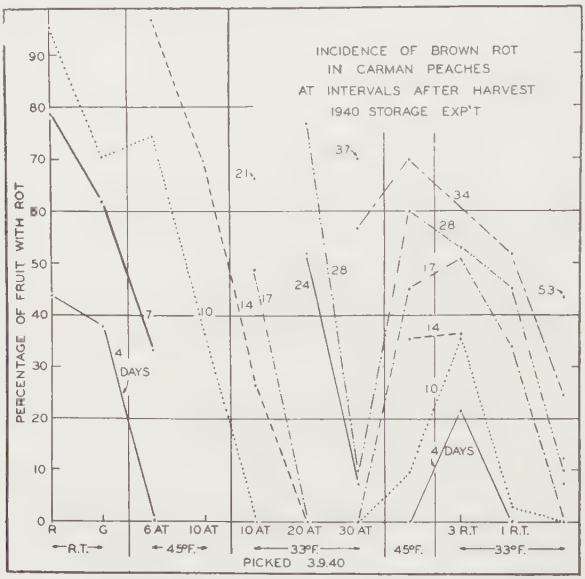

FIGURE 5. Incidence of brown rot in 1940 in Carman peaches. R. and G. at R.T. are riper and greener grades at room temperature. Storage periods are 6 and 10 days at 45° F. and 10, 20 and 30 days at 33° F. 3R.T. and 1R.T. signify 3 and 1 day delays at room temperature before storing at 33° F.

delay did not become apparent until after two weeks at 33° F., as the incubation period was prolonged by the low temperature. The successive occurrences of brown rot over extended periods, in the promptly cooled lots, demonstrate that infection takes place, though very slowly, even at 33° F.

Wastage from Rhizopus infection was negligible except in the Elberta storage experiment where it appeared 10 to 14 days after removal from the cold.

Experiments in 1941

In 1941, the incidence of brown rot for the first week after harvest, was low (8.9% for unsprayed Rochester and 4.8% for unsprayed Elberta) and the results of the spray tests were, in consequence, inconclusive. Comparatively little brown rot was observed in the storage experiments but Rhizopus rot was severe after the first 7 to 10 days at room temperature.

Experiments in 1942

Frequent rains and prolonged periods of high humidity during the greater part of the summer of 1942, as in that of 1940, set the stage for an outbreak of brown rot which culminated in a disastrous week during Elberta harvest. In spite of the fact that the Elberta peaches used for experimental purposes were picked under comparatively favourable conditions, just before the wet spell responsible for the major outbreak, a comparatively high percentage of brown rot developed (Figure 6). The Rochester pack also showed large amounts of brown rot in unsprayed lots.

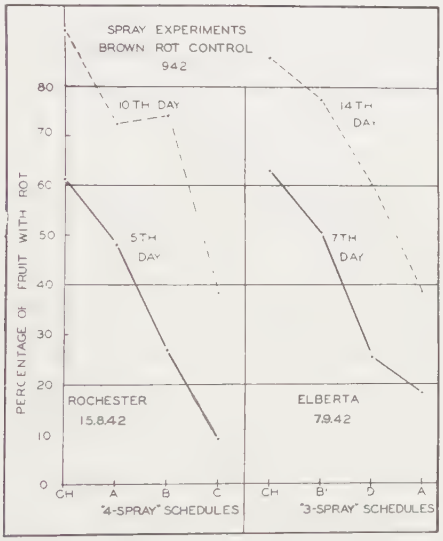

FIGURE 6. Incidence of brown rot in 1942 in Rochester and Elberta peaches. A, B, C and D represent different spray materials. B^1 indicates a single spray 18 days before harvest.

TABLE 5.—EFFECTIVENESS OF SPRAY SCHEDULES IN THE CONTROL OF BROWN ROT AT ROOM TEMPERATURE IN 1942

Variety	"3-spray" schedule					"4-spray" schedule					Single spray	
	Last spray	Rainfall		Control indices		Last spray	Rainfall		Control Indices		Control indices	
		Time*	Amount	1st week†	2nd week†		Time	Amount	1st week	2nd week	1st week	2nd week
			inches					inches				
		14	.28									
		12	.14									
		10	.25									
Rochester	16*	4	.12	—	—	2	2	.04	21.2	18.7	—	—
		3	1.00				1	.23	to	to		
		2	.04						85.5	57.7		
		1	.23									
		15	.14	59.2	29.6							
Elberta	18	10–11	.18	to 70.8	to 54.8	—	—	—	—	—	19.6	9.8

* Days *before* harvest. † After harvest.

On the whole, the response to spraying (Table 5, Figure 6) was fairly satisfactory considering the rainfall between the third and fourth sprays in the Rochester trial and the lack of a pre-pick spray in the Elberta trial. In its effects, the "3-spray" schedule program used for Elberta compared favourably with the "4-spray" schedule in the Rochester experiment, partly because of the difference in the amount of rainfall in the 2 weeks before harvest and partly because of an accidental wetting of some of the Rochester pack, which reduced the effectiveness of the spray materials almost in proportion to the extent of the wetting. As a result of this occurrence the spray material most efficient in controlling brown rot in the Elberta variety gave the poorest control with the Rochester.

The low control index for the "single spray" applied 18 days before harvest, as compared with the indices for the "3-spray" schedule, again demonstrates the importance of the earlier applications of the recommended progam, viz., the pre-blossom and shucks sprays.

Two experiments in the control of brown rot by means of sodium bisulphite tablets were also conducted. This method originated in South Africa (1, 2) for the control of moulds in packed grapes. These tablets, made up of 2 parts powdered anhydrous aluminium sulphite to 3 parts powdered sodium meta-bisulphite granulated with spermaceti, slowly evolve sulphur dioxide as they absorb water vapour. They were supplied in five sizes ranging in weight from 0.055 gram to 0.88 gram each, in doubling geometric progression. In the brown rot experiment, the tablets were wrapped singly in a piece of paper towel and distributed among unsprayed peaches at the rate of 1 to 4 of the larger sizes and 3 to 6 of the smaller sizes per 11 qt. basket.

Table 6.—Effectiveness of sodium meta-bisulphite tablets in the control of brown rot in unsprayed peaches at room temperature, in 1942

Tablet size	Rochester variety*					Elberta†
	1 tablet	2 tablets	3 tablets	4 tablets	6 tablets	3 tablets
.88 gm.	—	52.3†	—	65.0	—	22.4
.44 gm.	13.8	—	55.0	—	—	—
.22 gm.	28.5	26.1	44.0	—	—	10.9
.055 gm.	—	—	20.4	31.2	21.2	− 9.6

* Percentage brown rot in checks:—Rochester, **70.5**; Elberta **63.1**.
† Control index.

As indicated in Table 6, the tablets did effect some reduction in the amount of brown rot, which, with three exceptions, varied according to the size and number of the tablets used. While they were not as efficient as the conventional spray schedules, the tablets could be used under outbreak conditions to supplement spraying were it not for the fact that the larger tablets caused considerable injury. Under the conditions of the experiment from 5 to 22% of the fruits in a basket were damaged. Affected tissue appeared to have been "fixed" and partly bleached by the action of the chemical, and was delimited by a thin brown zone, forming in individual fruits a section of a sphere centred at the tablet.

DISCUSSION

It has long been recognized that weather conditions, particularly precipitation and humidity, coincident with harvest are of major significance in determining the severity of outbreaks of brown rot. But the

TABLE 7.—RAINFALL AND AVERAGE HUMIDITY FOR THE SUMMER MONTHS

Month	Rainfall						Rel. humidity (12 hr. av.)					
							A.M.			P.M.		
	14 yr. av.	1938	1939	1940	1941	1942	1940	1941	1942	1940	1941	1942
May	2.63	2.28	0.81	4.22	0.47	5.33	79.3	67.0	75.6	69.4	53.5	66.3
June	2.39	1.54	1.44	2.96	1.50	1.57	78.1	70.5	74.5	66.6	59.1	63.4
July	2.50	2.69	3.22	2.64	4.39	3.68	—	71.3	71.9	—	59.5	57.2
August	2.26	4.16	3.56	2.51	1.70	2.15	79.8	70.7	74.8	70.6	55.3	62.8
September	2.49	1.43	2.94	2.75	0.59	3.16	81.3	71.5	75.0	73.3	55.9	60.4
Average	2.45	2.42	2.39	3.02	1.73	3.18	79.7	70.1	74.5	70.1	56.7	62.4
Total June-Aug.	7.15	8.39	8.22	8.11	7.59	7.40	—	—	—	—	—	—

TABLE 8.—NUMBER OF DAYS ON WHICH RELATIVE HUMIDITY EXCEEDED 80% FOR 12 HOURS OR MORE, FOR 6 TO 12 HOURS AND FOR 0 HOURS

Month	R. H. 80% for 12 hrs. or more				R. H. 80% for 6 to 12 hrs.				R. H. not over 80%			
	1939	1940	1941	1942	1939	1940	1941	1942	1939	1940	1941	1942
May	5	15	3	11	9	8	8	8	6	2	11	2
June	5	9/23	5	8	13	6/23	7	15	3	3/23	6	0
July	2	—	7	4/23	13	—	4	7/23	1	—	5	2/23
August	10	10/26	2	9	14	11/26	9	10	1	1/26	6	4
September	8/25	18/27	2/22	5/23	6/25	5/27	10/22	9/23	1/25	0/27	5/22	2/23
Total	30	52	19	37	55	30	38	49	12	6	33	10
	148*	107	145	138	148	107	145	138	148	107	145	138

* Denominators, where used, indicate the number of days for which records were available.

foregoing experiments would suggest that the weather of the earlier part of the season may have considerable influence on the control of the disease through its effect on spore load and possibly on the inherent susceptibility of the fruit, giving rise to what might be termed the basic incidence for the season. For example, in 1940 when unsprayed peaches picked under favourable conditions were abnormally subject to brown rot, a high basic incidence may be postulated. In that year, the rainfall in May (Table 7) was much above normal, the average humidity was high and on 15 days relative humidity exceeded 80% for periods of 12 hours or more (Table 8). Conditions at blossom time were favourable for blossom blight and, though rainfall was not excessive in June, July and August (Table 7), the summer was characterized by frequent showers and protracted periods of damp

weather in which there was ample opportunity to build up inoculum. Except that conditions at blossom time were much better, the season of 1942, though less extreme, was similar to that of 1940, resulting in a moderately high basic incidence. In both years, as already mentioned, omission of the early sprays brought about a pronounced drop in the efficiency of the final spray application. Furthermore, since the "shucks" spray was dropped from one of the 1942 Elberta schedules with little or no loss of control, it may be concluded that under the conditions of the experiment and in spite of little blossom blight, the "blossom" spray was more important in brown rot control than "shucks" spray, which is primarily for curculio and scab. In 1939 and 1941, blossom blight was not a factor and in 1938, 1939 and 1941, drying days alternated more regularly with damp ones so that there was less opportunity for inoculum to accumulate. In these years, when one or other of the varieties tested showed comparatively small amounts of brown rot in unsprayed fruit during the first week after harvest and the basic incidence was presumably low, the brown rot losses in Elberta in 1938 and in Rochester in 1939 were attributable to unfavourable conditions just before or during harvest when a rapid local increase in the quantity of inoculum could and probably did take place.

A comparison of the control indices, Tables 2 to 5, suggests that control by spraying, as might be expected, was more difficult in years of high basic incidence. This was particularly true of the 1940 season. However, the effectiveness of a spray program may also be modified by other factors such as sulphur content, particle size, and adhesive properties of the spray materials, coverage, timing of sprays, amount and nature of precipitation between spraying and harvest, harvesting conditions, wrapping of the fruit, etc. Evidence of the operation of some of these factors has already been noticed in the reports on individual experiments, but from the data in hand, it is difficult to assess their relative significance or to account satisfactorily for all the fluctuations in efficiency. Suffice it to say, that, in general practice, the long-range unpredictability of local weather and the possibility of narrow margins, between favourable and unfavourable harvesting conditions makes it necessary to apply all the recommended sprays as an insurance measure and to time the third spray at no more than 3 weeks and the pre-pick spray 1 or 2 days before harvest is expected. As the sprays are more fungistatic than fungicidal and therefore tend to delay rather than to prevent infection, spraying should not be looked upon as a substitute for other precautions. For example, peaches should not be handled while they are wet nor allowed to get damp after being picked and the necessary precautions should be taken to minimize the possibilities of contamination during picking and packing, if satisfactory control of brown rot is to be achieved.

With regard to refrigeration of peaches, these experiments have shown that infection by brown rot can take place at temperatures as low as 33° F., even though the incubation period is long. Ordinarily, temperatures of 45° F. or lower will delay infection long enough for commercial purposes, but it is of interest to note that the rate of incidence of brown rot after removal from the cold tends to drop with the lower refrigerating temperature and to rise with the longer refrigeration period. If, however, the initial stages of infection have already taken place before the fruit is chilled,

the advantages of refrigeration are likely to be lost. For this reason, the importance of the careful selection of disease-free fruit and prompt packing and cooling cannot be overemphasized, especially in seasons when the basic incidence is likely to be high. In such years, pre-cooling the pack before refrigeration for the rapid removal of field heat is highly to be recommended. By the same token, efforts should be made to have peaches promptly despatched and rapidly distributed, where shipping without refrigeration is in order.

SUMMARY

1. In the years 1938 to 1942, inclusive, a 4-spray schedule, comprising sprays early in blossom time, at shuck fall, 2 to 3 weeks before harvest and just before picking reduced brown rot incidence during the first week after harvest by 40 to 65% in the worst years and by 65 to 100% in other years.

2. In view of the possibility of a rapid build-up of inoculum at any time during the growing season, omission of any of the sprays in the regular schedule is likely to reduce the efficiency of the spray program.

3. Wrapping peaches in tissue tends to add to the effectiveness of spraying by reducing chance contamination in the pack.

4. Infection can take place at temperatures as low as 33° F. but the incubation period is greatly prolonged so that, for practical purposes, prompt refrigeration at or below 45° F. is satisfactory. In long distance shipping where transportation exceeds one week a temperature of 33° F. is recommended. For shorter hauls 45° F. suffices.

5. The rate of incidence of brown rot during the first few days after removal to room temperature is lowered as the holding temperature in the cold store approaches 32° F. but tends to rise as the time in cold store lengthens.

6. Rot caused by black mould, *Rhizopus nigricans*, was not observed on peaches during refrigeration, but may be serious after storage. It seldom appeared in peaches at room temperature until the second week after harvest unless the pack was damp. It tends to spread from fruit to fruit to form nests of rot, to a greater degree than does brown rot. Rhizopus rot does not appear to be amenable to spraying.

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THE USE OF CORN GLUTEN FEED TO REPLACE MEAT MEAL IN POULTRY RATIONS[1]

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Corn gluten feed or gluten feed is a by-product of the starch and glucose industry. This feedstuff should be distinguished from corn gluten meal which is also a by-product of the same industry, the difference being that corn gluten feed usually contains between 23 and 25% protein, whereas corn gluten meal will contain around 40 to 45% protein.

Corn gluten feed has been used successfully in rations for beef cattle, horses, sheep and swine and it is one of the commonest protein supplements used in the feeding of dairy cattle. Sloan (4) has indicated that although corn gluten feed may be used in poultry rations, it is not as satisfactory a protein concentrate as soybean oil meal.

According to Morrison (1), the quality of the protein of corn gluten feed is similar to that of corn and therefore is deficient in at least two essential amino acids, namely, lysine and tryptophane.

I. THE USE OF CORN GLUTEN FEED AS A PROTEIN SUPPLEMENT IN A RATION FOR GROWING CHICKS

This experiment was conducted to determine the extent to which corn gluten feed can be used to replace meat meal in a good chick starting ration. Eight groups of birds were used, each group being composed of 34 Barred Plymouth Rock chicks, half of which were pullets and half cockerels. The general experimental procedure and the details of management and of the method of formulating the rations have been presented in an earlier paper (Pettit *et al.* (2)). In the present study, the feeding trials were continued for 10 weeks and the chicks were weighed at weekly intervals.

The composition of the basal mixture which was used for each 100 pounds of feed is presented in Table 1.

Table 1.—Basal Mixture

Ingredient	Weight
	lb.
Ground oat groats	18.0
Ground yellow corn	18.0
Ground wheat	18.0
Cereal grass	1.0
Dehydrated alfalfa	2.5
Buttermilk powder	10.0
Salt*	1.0
Steamed bone meal	1.0
Oyster shell	1.0
Grit (insoluble)	1.0
Cod liver oil**	0.25
Total	71.75

* Contained 0.02% KI and 2.0% $MnSO_4 \cdot 4H_2O$.
** Contained 400 A.O.A.C. units of vitamin D and 3000 I.U. of vitamin A per gram.

[1] A contribution from the Departments of Poultry Husbandry and Animal Nutrition of the Ontario Agricultural College. J. Walker and E. C. Roberts assisted with the project and a part of the work reported herein was presented in their undergraduate thesis in partial fulfilment of the requirements for the Degree of Bachelor of Science in Agriculture (1943).

Table 2 shows the ration composition, mortality data, feed consumption and average live weight at 10 weeks of age for each group while the average weekly weights and gains are presented in Figure 1.

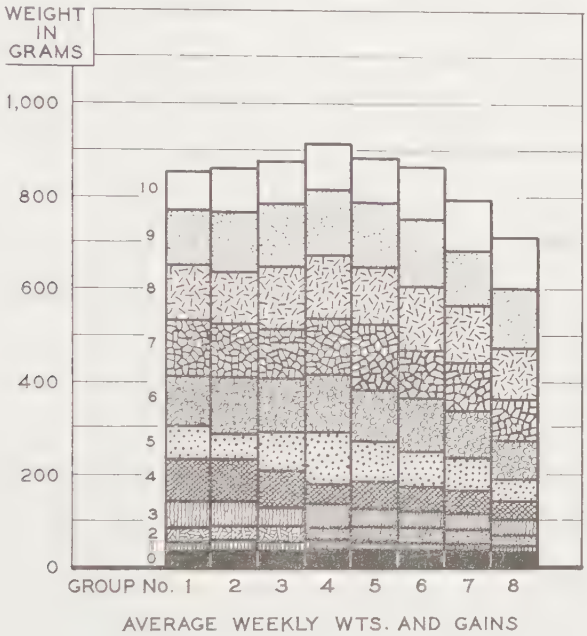

FIGURE 1.—AVERAGE WEEKLY WEIGHTS AND GAINS

TABLE 2.—CORN GLUTEN FEED IN STARTING RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
Basal (%)	71.75	71.75	71.75	71.75	71.75	71.75	71.75	71.75
Meat meal (%)	10.50	9.00	7.50	6.00	4.50	3.00	1.50	—
Ground barley (%)	17.75	16.25	14.75	12.25	8.75	7.25	4.25	2.25
Corn gluten feed (%)	—	3.00	6.00	10.00	15.00	18.00	22.00	26.00
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Mortality	3	1	4	0	0	1	0	2
Feed consumption (lb.)	214.5	205.5	217.5	216.0	221.5	216.7	212.5	211.0
Average weight at 10 weeks (gm.)	848.0	860.8	885.1	910.2	879.4	858.4	789.9	707.8

The 10-week weight data were analysed for significance by the method of "weighted squares of means". This method, proposed by Yates (6), has been adapted for the interpretation of data from chick nutrition experiments by Titus and Hammond (5). Tests of significance were made by means of the F test (Snedecor (3)). Since the F value for diet exceeded the 5% point, it may be concluded that the weights were significantly different, therefore making further analysis necessary. By application of

the t test to the differences between the unweighted mean live weights of males and females on any two different diets, the results presented in Table 3 were obtained.

TABLE 3.—SIGNIFICANCE OF DIFFERENCE BETWEEN DIETS

Group No.	Significantly better than	Significantly poorer than
1	7, 8	3, 4, 5
2	7, 8	4
3	1, 7, 8	4
4	All	None
5	1, 7, 8	4
6	7, 8	4
7	8	All but 8
8	None	All

It will be noted in Figure 1 that, as the meat meal was replaced by corn gluten feed, there was a gradual increase in the maximum weights attained by successive groups 1 to 4 and a gradual decrease thereafter, indicating a decided optimum when the ration contained 10% of corn gluten feed and 6% of meat meal. When more than 18% of corn gluten feed was included in the ration (groups 7 and 8), the maximum weights attained were significantly lower than the control group (Table 3). This would seem to indicate that with such high levels of gluten feed replacing meat meal, the ration is rendered deficient in some nutrients (possibly amino acids) essential for most rapid growth.

As will be noted in Table 3, corn gluten feed in concentrations as high as 26% of the ration did not affect feed consumption, indicating that this feedstuff is not unpalatable to chickens. In addition, since no mortality resulted from feeding relatively high levels of corn gluten feed, it would appear to be quite a safe feed for chickens.

II. CORN GLUTEN FEED IN LAYING AND BREEDING RATIONS

This experiment was planned to evaluate corn gluten feed as a protein supplement in a layer-breeder mash. Four groups of 25 Barred Plymouth Rock pullets with 2 cockerels per group were used. The general experimental method used was described in a previous paper (Pettit *et al.*, (2)). The test period in the present case was 10 months. Egg production was recorded for the whole period, and hatchability was determined over a period of 3 months.

The basal mixture which was used for each 100 pounds of mash is presented in Table 4.

Mash was before the birds at all times and grain which regularly was fed before the birds went to roost was furnished on a per diem basis of $3\frac{1}{2}$ lb. per group. The grain mixture consisted of 1 part oats, 1 part corn and 2 parts wheat. Oyster shell, grit and bone meal were fed *ad libitum* in a separate hopper.

TABLE 4.—BASAL MIXTURE

Ingredient	Weight
	lb.
Ground yellow corn	12.5
Crushed oats	18.0
Rolled oat groats	5.0
Ground wheat	13.0
Wheat middlings	5.0
Wheat bran	10.0
Wheat shorts	12.5
Ground barley	10.0
Soybean oil meal	7.5
Bone meal	1.5
Oyster shell	1.5
Molasses	2.25
Salt*	1.25
Total	100.00
$MnSO_4 . 4H_2O$	0.6 oz.

* Contained 0.02% KI.

The composition of the rations is shown in Table 5.

TABLE 5.—COMPOSITION OF THE RATIONS

Ingredient	Group 1	Group 2	Group 3	Group 4
	%	%	%	%
Basal	67.25	64.75	61.75	56.75
Ground yellow corn	10.75	10.75	10.75	10.75
Buttermilk powder	6.00	6.00	6.00	6.00
Meal meal	10.50	9.50	8.00	5.00
Corn gluten feed	—	3.50	8.00	16.00
Dehydrated alfalfa	5.00	5.00	5.00	5.00
Cod liver oil*	0.50	0.50	0.50	0.50
Total	100.0	100.0	100.0	100.0

* Contained 400 A.O.A.C. units of vitamin D and 3000 I.U. of vitamin A per gram.

TABLE 6.—CORN GLUTEN FEED IN LAYER-BREEDER RATIONS

Group	Egg production Nov. 1/41 to Aug. 31/42		Total fertile eggs set	*Hatchability Feb. 1/42 to April 30/42			
				Feb.	March	April	Average
	Total	%		%	%	%	%
1	4146	54	1178	70.3	66.9	57.0	64.5
2	3850	50	996	75.5	70.4	70.0	72.1
3	4177	55	1064	62.7	66.2	60.9	63.6
4	4512	59	1211	65.8	68.3	73.1	69.1

* Based on fertile eggs set.

Figure 2 shows the distribution of the embryonic mortality. Table 6 shows the egg production results for the 10 month experimental period and the hatchability results for the 3 months, February, March and April.

As shown in Table 6, there were only minor differences in egg production between groups. The hatchability results varied somewhat from

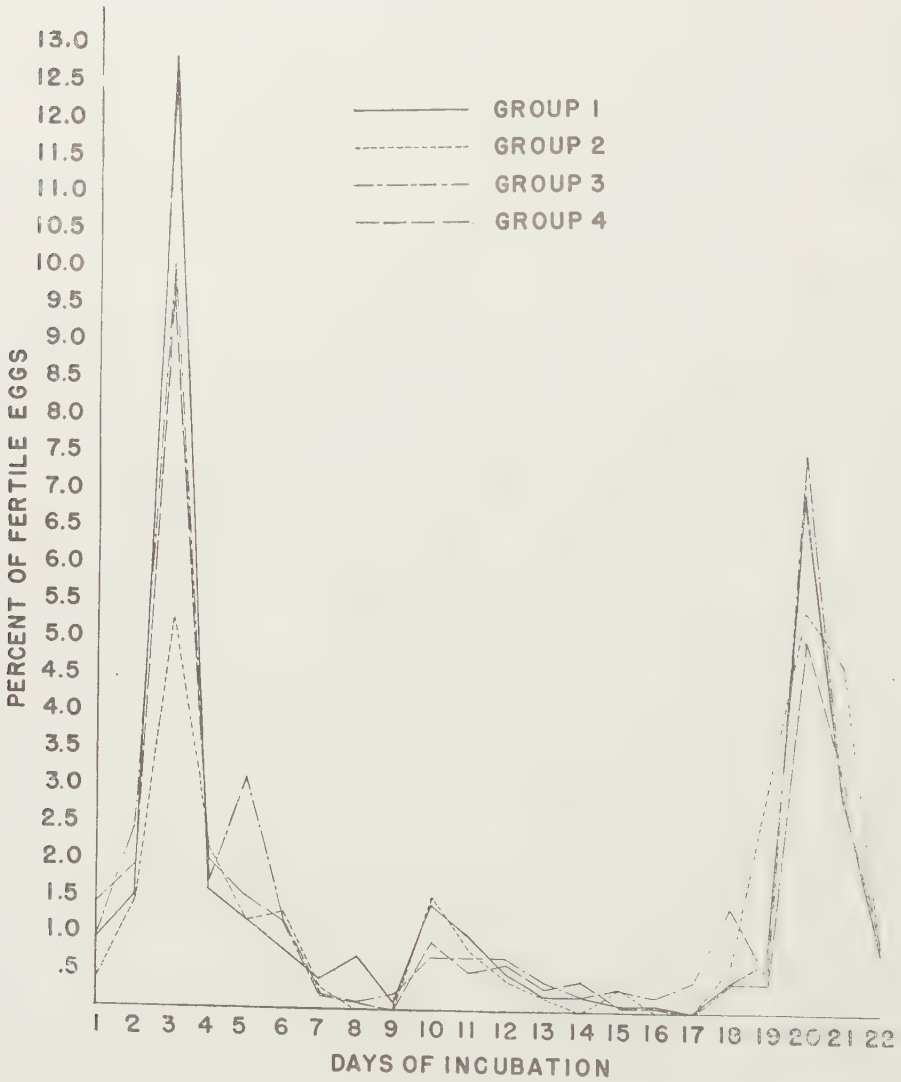

Figure 2.—Distribution of Embryonic Mortality

month to month but the differences between the average hatchability figures are not great. The percentage hatchability of group 1 declined to a greater extent than that of groups 2 or 3 as the season advanced, while the hatchability in the case of group 4 showed some increase with the advancing season. This would seem to indicate that too high a concentration of meat meal in the ration is not desirable from the point of view

of maintaining hatchability throughout the season and that the substitution of up to half of the meat meal by corn gluten feed improves the ration considerably in this regard.

As indicated in Figure 2 all groups had high embryonic mortality peaks on the third, twentieth and twenty-first days, with comparatively little mortality at any other period of incubation. In comparison with the other groups, the third day peak for group 2 was low, while the control group had the highest mortality at this time. A monthly summary of this early incubation peak indicated certain trends—whereas the third day mortality was practically constant each month for group 2, that of groups 3 and 4 declined with advancing season and in the case of the control group there was a considerable increase in embryonic deaths at this time as the season advanced. In all groups, approximately 50% of the embryos dying on or after the eighteenth day of incubation were found to be in a malposition within the shell.

Since production and hatchability results are equally good when as much as 16% of corn gluten feed is included in the mash to replace meat meal as when none of the meat meal is replaced, it would appear that corn gluten meal is a satisfactory substitute for at least a part of the meat meal in a layer-breeder mash.

SUMMARY

Corn gluten feed was used as a vegetable protein supplement to replace meat meal in a ration for growing chicks and in a ration for laying and breeding birds. The meat meal was replaced by successively larger amounts of corn gluten feed until 26% was included in the ration to replace all of the meat meal in the chick starting ration and 16% was included to replace half the meat meal in the layer-breeder mash.

From the results of the growth trials it may be concluded that corn gluten feed is a suitable vegetable protein supplement to replace part of the meat meal in a ration for growing chicks. In such a ration as here employed, it may be used satisfactorily to form up to 18% of the diet, with an optimum at around 10%. When levels of 22 and 26% of corn gluten feed were used, the growth rate was somewhat reduced but the ration remained quite palatable and caused no mortality.

The results of the production and hatchability studies indicate that under the conditions of the experiment, corn gluten feed may be used in the mash to replace part of the meat meal on a protein equivalent basis in amounts up to 16%.

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LEVEL AND SOURCE OF PROTEIN IN POULTRY PRODUCTION

II. AS RELATED TO ECONOMICAL PRODUCTION OF EGGS[1]

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In a paper covering the rearing phase of this project (5) the comparative efficiency of different levels of protein from vegetable or animal sources averaging approximately 12.5%, 14.5% and 17% for the production of growth was determined. It was concluded that 12.5% of protein was too low and that, with reasonable supplementation by pasture, the intermediate level so closely approximated the highest level in results, actually surpassing it with respect to efficiency of use of protein and economy of production of body weight, that a saving of 2.5% of protein could safely be made in this way. It was realized that it was necessary to demonstrate that no ill effect of this lower protein level would be produced which might carry over into the period of egg production, and possibly nullify the value of the saving made during the rearing period. It had been originally planned that this project should include the egg production phase to determine whether levels of protein lower than those generally recommended might not be used for this purpose with equally as good results or with a sufficient degree of satisfaction to justify their use in a time of protein scarcity such as has been brought about by the present crisis. The plan of experiment involved an extension of the work of evaluation of supplementary vegetable protein as a substitute for the major proportion of the animal protein feeds of the ration, to cover the period of egg production. The experimental technique actually used in this experiment also made possible an assay of the comparative merits of the environmental conditions of the laying battery as opposed to the usual laying house method of management.

For a survey of the subject of protein and egg production, reference should be made to the recent review by Heuser (6). In general it seems to be conceded that within a reasonable range of protein levels, increased production may be expected as the level increases. If efficiency and economy are considered as well as absolute degree of production obtainable, however, it becomes obvious that an upper limit exists which is dictated by a proper balance between these factors. In general there is agreement that levels of protein in the neighbourhood of 12% would seem to be inadequate.

A large amount of research is on record dealing with the adequacy of soy bean meal as a substitute for animal protein ingredients of the ration. It seems obvious from a review of this work that this product requires some supplementation in the nature of both vitamin and protein additions. (1, 2, 4). Even with supplementation such a ration might not be efficient

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when fed to pullets which had been raised on a diet whose proteins came largely from a vegetable rather than animal source. This part of the present experiment was planned to obtain information in answer to this question.

EXPERIMENTAL

The pullets which were used in the rearing phase of this experiment were placed in laying quarters on November 1 at which time a small number of pullets in each of the medium and high animal protein groups as well as one pullet in the high vegetable protein group were laying. One-half of all birds was placed in laying batteries and the other half in laying house pens the division being made by random selection. At the beginning of the experiment there was a similar number of birds in the laying house and in the battery which had been reared on each of low, medium and high animal protein, and low, medium and high vegetable protein. In the laying house the birds were again divided at random to form alternate duplicate pens on each treatment, a technique calculated to increase the reliability of the results obtained through replication. The degree of agreement between such duplicates represents a rather exacting test of the reliability of the sampling technique as well as of the control of environmental conditions. All birds were randomized over 3 laying batteries of 3 tiers each according to treatment, battery and tier. In view of the marked effect of light dosage on egg production, all natural light was excluded, and replaced by artificial light adjusted to give similar exposure in all parts of the battery in so far as it was possible to judge by the use of an electric photometer. It should be understood that the group that received low animal protein during the growing period also received the lowest protein ration during this period of egg production and similarly for the other groups involved. The experiment as originally planned called for one-half of each group to be carried upon the same actual protein level as was used during the rearing period, and one-half to revert to the protein levels usually used during the egg production stage as a more accurate check upon the effect of the rearing treatment on subsequent production. This was found to be impractical, however, without reducing the number of birds per treatment to a dangerously low level in the statistical sense.

The rations fed were all-mash in nature and are shown in detail in Table 1. The ingredients of these rations, as originally made up, were adjusted to produce the analysis required as estimated from tables of analysis of feeds. When samples were chemically analysed, adjustments were made in the amount of corn starch to bring the analyses to the desired levels for all nutrients which were of principal concern. It will be noted that the protein levels actually fed were 12.5%, 14.5% and 16.5% for low, medium and high, respectively. All rations were adequate in riboflavin for egg production and this factor was increased to a level sufficient for hatchability before and during the period when eggs were being saved for hatching, by the addition of pure crystalline riboflavin. It should be pointed out also that the protein supplements (meat meal, fish meal and buttermilk powder) varied proportionately from level to level thus further

TABLE 1.—INGREDIENTS AND CHEMICAL ANALYSES OF RATIONS USED

	Animal protein			Vegetable protein		
	Low	Medium	High	Low	Medium	High
	%	%	%	%	%	%
Ground scratch grain	40	40	40	40	40	40
Ground oats	15	16	16	15	15	16
Wheat bran	7	7	7	7	7	7
Wheat shorts	6	6	7	6	6	7
Corn starch	20	16	12	18	14	8
Dehydrated alfalfa leaf meal	3	3	3	3	3	3
Buttermilk powder	1	2	3	2.5	2.5	2.5
Meat meal	1	2	3	—	—	—
Fish meal	1.5	3	4.5	—	—	—
Soy bean meal	—	—	—	2	6.5	10
Bone meal	2	1.5	1	3	2.5	3
Oyster shell	3	3	3	3	3	3
Salt (iodized)	0.25	0.25	0.25	0.25	0.25	0.25
Cod liver oil	0.25	0.25	0.25	0.25	0.25	0.25
Manganese sulphate ($\frac{1}{4}$ lb. per ton)						
Totals	100.0	100.0	100.0	100.0	100.0	100.0
Moisture	10.05	10.51	10.50	9.90	9.90	10.06
Protein	12.50	14.50	16.50	12.50	14.50	16.50
Fat (ether extract)	2.49	2.60	2.87	2.71	2.77	3.02
Ash	6.10	6.16	5.93	5.76	6.31	6.04
Fibre	4.90	4.15	4.23	4.32	4.82	4.67
Carbohydrates	63.96	62.08	59.97	64.81	61.70	59.71
Totals	100.0	100.0	100.0	100.0	100.0	100.0
Calcium	2.23	2.32	2.08	2.02	2.17	2.17
Phosphorus	0.72	0.82	0.77	0.74	0.74	0.74

assuring that differences were due to level of protein uncomplicated by variation in the ratio of proteins of different characteristics such as amino acid constitution.

Complete substitution by soy bean meal for meat and fish meal was not attempted. An amount of 2.5% of the total ration or 0.85% of protein in each of the vegetable protein rations came from milk powder fed largely as a source of riboflavin but also because it is particularly efficient (1) as an amino acid supplement to soy bean meal. Throughout this paper the term vegetable protein will be used with reference to the rations whose supplementary protein is largely from a soy bean meal source the small amount of animal protein supplementation being understood.

The criteria used to assay the effects of the experimental treatments in this test were as follows: egg production (365-day and biological year) egg weight, weight of first 10 eggs, average body weight, maximum body weight, feed consumption and days to first egg, all on a per bird basis. In the case of the birds in the laying houses, feed consumption was available only for each pen. Egg weights were taken weekly throughout the test and body weight and feed consumption at 28-day periods. Both mortality and hatchability were also considered, the former on the basis of individual autopsy and the latter on the basis of the hatchability for each bird.

The data were subjected to exhaustive statistical analysis by the methods of variance and covariance and each criterion was adjusted for the effect of all pertinent correlated variables as follows: egg production adjusted for the effect of days to first egg, maximum body weight, average body weight and feed consumption; egg weight for days to first egg, weight of first 10 eggs, maximum body weight and feed consumption; weight of first 10 eggs for production, egg weight, maximum body weight and days to first egg; maximum body weight and average body weight for production, egg weight, feed consumption and days to first egg; feed consumption for egg weight, production, maximum body weight and average body weight. Correction was made to the adjusted means according to the technique elaborated by O'Neil and Gutteridge (7). In the case of feed consumption, which was not available on a per bird basis for the birds in the laying house, the variability determined for the birds in the laying battery was used. On analysis, no significant difference occurred between the replicate pens on the same treatment in the laying pens, an indication of satisfactory control of environment and that the data from these replicate pens could be combined for statistical analysis, which was done.

RESULTS

The data covering the 365-day period of the test are summarized in the following tables.

TABLE 2.—OBSERVED AND ADJUSTED MEAN VALUES FOR LOW, MEDIUM AND HIGH LEVELS OF PROTEIN†

	Observed means			Adjusted means		
	Low	Medium	High	Low	Medium	High
	%	%	%	%	%	%
Egg production	150.2	178.0	185.5	159.6	178.1	176.5
Egg weight (gm.)	55.40	57.10	58.21*	55.44	57.09	58.16*
Weight of first ten eggs (gm.)	54.16	53.73	53.45	54.49	53.83*	52.96
Average body weight (lb.)	5.37	5.94	6.05	5.24	6.05	6.07
Maximum body weight (lb.)	6.14	6.58	6.67	6.26	6.62	6.51
Feed consumption (gm./day)	118.3	122.3*	127.8	127.6	119.4	121.4
Days to first egg	240.6	227.7	219.4*	237.8	228.4	221.4*

* Significantly superior values when compared at $p = 0.05$ between high and medium protein levels.
† Number of birds—low 122; medium 128; high 116.

Actual differences and necessary differences are not quoted for the sake of brevity. Between medium and low, and high and low protein levels all differences are significant for all criteria, and, with the exception of feed consumption and weight of first 10 eggs, favourable to the higher levels of protein. As well as being significant the differences are sufficiently great to be of some practical importance, and on the basis of these data a level of protein as low as was used in this test, namely, 12.5%, is too low for purposes of egg production.

Between high and medium levels of protein differences are smaller. The difference of 7.5 eggs in observed production is not significant and therefore may be due to chance rather than to the level of protein. Egg

weight and days to first egg significantly favour the high protein level but by differences of only 2% and 3.7%, respectively. Feed consumption was lower on the medium protein level. Considering the adjusted means, in which allowance has been made for the effect of days to first egg, maximum body weight, average body weight and feed consumption upon egg production it is seen that no direct effect of protein level on egg production *per se* has been brought about, the observed difference being due to the influence of these characters which could not be controlled but could be and were measured, rather than to rate or persistency or other factors which go to make up the complex, egg production. Since the rearing treatment had a definite effect upon days to first egg (5) the adjustment for these factors is particularly necessary if a comparison of these groups on the basis of egg production is to be unbiased. High protein did have a direct favourable effect upon egg weight and days to first egg as was the case also with the observed means although the actual differences were small. The lower level of protein was slightly more favourable to large egg size in the first 10 eggs. On the basis of the same egg weight, body weight and egg production, feed consumption of the medium protein group was almost identical with that of the high protein group thus giving at least equal efficiency in use of feed. No effect of medium as opposed to high protein level either direct (adjusted means) or indirect (observed means) upon average or maximum body weight was found in these data.

The results of the comparison of animal and vegetable protein sources are show in Table 3.

Table 3.—Observed and adjusted mean values for animal and vegetable protein sources†

	Observed means		Adjusted means	
	Animal protein	Vegetable protein	Animal protein	Vegetable protein
Egg production	174.2	167.5	172.7	169.4
Egg weight (gm.)	56.97	56.82	57.43*	56.26
Weight of first ten eggs (gm.)	53.12	54.57*	53.19	54.44*
Average body weight (lb.)	5.79	5.78	5.86*	5.69
Maximum body weight (lb.)	6.46	6.46	6.50	6.41
Feed consumption (gm./day)	121.9	123.8	121.4*	124.5
Days to first egg	224.7*	234.7	224.6*	234.5

* Significantly superior values when compared at $p = 0.05$.
† Number of birds—vegetable protein 164; animal protein 202.

No significant difference occurred (observed means) between animal and vegetable protein groups excepting in weight of first 10 eggs and days to first egg. That the weight of the first 10 eggs should be higher for the slower maturing group is reasonable in view of a correlation of + 0.5 between these characters in these data.

The adjusted means indicate that the apparent difference in production in favour of the animal protein group is probably due to correlated factors such as days to first egg and feed consumption, as indicated by a large reduction in the difference when allowance is made for these factors, rather

than to a direct effect of source of protein upon production. Animal protein was favourable to maintenance of a high average body weight and egg weight, to a more efficient use of feed for production, maintenance and egg size, and to more rapid sexual maturity. The last mentioned difference of 10 days in sexual maturity is the difference of greatest practical importance and this might be considered therefore to be the most potent effect of animal protein in this test.

Table 4 shows the pertinent data for the birds kept in laying batteries and in laying houses.

TABLE 4.—OBSERVED AND ADJUSTED MEAN VALUES FOR PULLETS KEPT IN BATTERIES AND IN LAYING PENS†

	Observed means		Adjusted means	
	Battery	Laying pens	Battery	Laying pens
Egg production	184.1*	157.7	188.2*	153.7
Egg weight (gm.)	57.01	56.77	58.5*	55.2
Weight of first ten eggs (gm.)	51.74	55.94*	52.2	55.4*
Average body weight (lb.)	5.99*	5.57	6.45*	5.08
Maximum body weight (lb.)	6.65*	6.27	6.95*	5.94
Feed consumption (gm./day)	115.0*	131.1	111.1*	135.4
Days to first egg	220.1*	238.9	221.5*	237.5

* Significant differences at $p = 0.05$.
† Number of pullets—battery 187; laying pens 179.

A difference of 26 eggs in favour of the battery method of housing of laying pullets proved to be a real effect of the environment of the laying cage when it became a difference of 34 eggs per bird after making allowance for the effect of the other pertinent uncontrolled variables. In every criterion excepting weight of first 10 eggs, the battery gave superior results, and this exception may be explained by the relationship between this character and days to first egg previously noted. The differences are, for the most part, of high magnitude and represent an effect of practical importance. A point of considerable importance is the fact that the additional egg material was produced, and the higher body weight built up and maintained on a much lower feed consumption for the birds in the battery. These effects were due, without doubt, to the saving of feed brought about by the supplying of heat to a moderate temperature in the battery room, thus lowering the feed requirement for maintenance of body temperature and by the enforced inactivity of the birds in the cages with its concomitant saving of feed for energy production.

Biological Year Production

In view of the fact that the pullets used in this experiment were relatively late hatched, the possibility existed that the most retarded groups, when their production for 365 days from the time of entering the laying house was used, would be discriminated against in that their production might persist longer into the early winter and that they might eventually make as high production as some of the groups whose date of

first egg was much earlier. Production was therefore recorded for all the birds in the battery until they went into the moult which did not occur in some instances until the end of January or 15 months from the beginning of the test. The average production of all groups was some 10 to 15% higher on this basis, but the relation between production on the three protein levels and the two protein sources was essentially the same as for the period covered by the data already reported. It is of interest to note that rate of production, i.e., number of eggs laid during the biological laying year divided by the number of days from first to last egg, did not differ significantly for animal and vegetable protein nor for medium and high protein levels but did so significantly for medium and high protein levels over low level.

Hatchability

As previously stated all rations fed in this test contained sufficient riboflavin to meet requirements for production and hatchability. After the data from those individuals which had given no fertility were eliminated from consideration the remaining data were expressed as degrees of an angle (3) preparatory to statistical analysis. No differences between protein levels were significant and the actual hatchability of fertile eggs was as follows: low protein 77.9%, medium protein 73.5% and high protein 75.1%; animal protein 78.5%, vegetable protein 71.7%. It seems obvious that level of protein had no effect on hatchability, but that the animal source did give significantly superior results to the vegetable, by 6.8% in this instance.

Mortality

Mortality and cause, as determined by autopsy, were tabulated. No trend of any kind was exhibited in so far as cause is concerned. As to level of mortality the figures were: battery 18.6%, laying pens 19.5%; animal protein 17.5%, vegetable protein 18.9%; low protein 17.4%, medium protein 13.3%, high protein 23.3%. When the month to month mortality was compared statistically by the binomial method the mortality of the high protein group proved to be significantly greater than that of the medium and low protein groups. All other differences were non-significant. It would seem therefore that the highest protein level was a greater predisposing factor to mortality than any other of the protein levels under experiment.

Cost of Production

The adjusted means for feed consumption, shown in Tables 2, 3 and 4, are admirably suited for use as a basis for comparison of cost of production since they represent the feed used by each group to produce the same number and size of eggs and maintain the same body weight. On this basis for the year's production, the medium level of protein was more economical than the low and high levels by 6 cents and 13 cents per bird, respectively; the animal than the vegetable protein by 4 cents; and the battery than the laying pen by 35 cents per bird. These figures represent feed costs only.

DISCUSSION

Level of Protein

Barred Rock pullets when reared on a low protein ration (average protein 12.5%) and subsequently carried through a laying year on a similar ration containing the same level of protein, failed to give satisfactory results as judged by the following criteria: egg production, egg weight, body weight, and days to first egg. Suitable statistical treatment of the data showed that to a moderate degree the low production obtained was due to delayed sexual maturity, as when allowance was made for the effect of this factor the production was somewhat increased. Even after such adjustments were made, however, the average production per bird was still some 17 eggs lower than the next highest protein level, hence it is obvious that as low a level as 12.5% of protein in the laying ration has a direct retarding effect upon egg production. Since the lower level of protein feeding during both the rearing and production periods must be considered to be responsible for the retarded sexual maturity, the lower production of 28 eggs per bird must be debited to the lower level of protein feeding.

Between medium and high protein levels differences are not great. Setting aside the effect of days to first egg, which is largely a result of rearing treatment, no direct difference in effect of high or medium level of protein was measurable and it may be stated that the high level of protein used in this test during the period of egg production did not affect the rate of production of eggs. It did, however, favourably affect the size of the egg in spite of the tendency for the more rapid sexual maturity induced by a high protein level to produce a lower weight of the first eggs laid.

Considering the total period of the experiment from hatch to the end of the laying period, the most striking effect of variation in protein level is that upon sexual maturity (days to first egg). The lowest protein level seriously retarded sexual maturity and the medium level significantly so, although by only 8 days as against 21 days in the case of the lowest level.

Cost per unit of production is the final criterion in determining the usefulness of any treatment and on the basis of equal performance in production, egg size and body weight a saving of 13c. per bird per year in economy in feed cost was made in using the moderate level (14.5%) of protein rather than the high level (16.5%), whereas a saving of only 6c. per bird was made by the use of the low level (12.5%).

Source of Protein

Animal protein was significantly superior to vegetable protein in body weight and feed consumption and in rate of sexual maturity, which, as previously noted, is largely traceable to the effect of vegetable protein in the rearing phase. Egg weight and weight of first 10 eggs favoured the vegetable protein source. Under the circumstances it would seem that substitution of vegetable protein (soy bean meal) for the animal protein supplements was more satisfactory for egg production than for rearing of pullets (5). It is reasonable to believe, in view of published information with regard to protein levels in rearing, that this period is somewhat more exacting than the period of egg production from the standpoint of source of

protein, possibly because of greater requirements for specific amino acids for growth as against maintenance and production of eggs. Hatchability was also superior for the birds on animal protein.

Battery vs. Laying House

With one exception all criteria indicate the superiority of the laying battery as opposed to the laying pen. The one exception, weight of first 10 eggs, represents a very large difference in egg weight which tentatively must be explained by slower maturity in the laying pens, with probable greater body weight at date of first egg as against a depressing effect upon early egg size in the battery brought about by the reverse of the above conditions. The high positive correlation of body weight on egg weight and of days to first egg on weight of first 10 eggs suggests that as a possible explanation. This is not borne out, however, by the adjusted means in which allowance is made for the effect of the factors mentioned. Actually, the elevating effect of late sexual maturity upon weight of first 10 eggs in the case of the laying pen was counteracted by an early high rate of production in the laying battery, indicating that the large difference still existing after adjustment was a direct effect of the environment of the laying cage. That this early advantage of the laying pen did not persist is evidenced by the significantly and considerably higher egg size in the battery on the average over the whole period of the test. Although starting on equal terms, the environment of the laying cage was responsible for the production of many more and larger eggs, a larger body weight and a much more rapid sexual maturity, all this accomplished on a very much lower feed consumption. The last mentioned factor was of course, due to the decreased requirement for feed to support activity and body temperature in the restricted space of the laying cage and the partially heated air of the battery room. In terms of economy of efficiency of production, 18% less feed, valued at 35 cents per bird, was required to make the same production, egg size and body weight. When the market value of the additional production is considered the laying battery proves to be very much superior to the laying pen.

It should be realized that the favourable effect of the battery environment would not necessarily be evidenced to so great a degree if early hatched pullets, already mostly sexually mature, were being used. For moderately late hatched birds (May 15) under climatic conditions similar to those of this area, a decided improvement in production, egg weight and body weight may be expected.

SUMMARY

Barred Rock pullets which had been reared on low (12.5%), medium (14.5%) or high (17.0%) protein levels, of which the supplementary protein came from either animal or largely vegetable sources, were continued during the period of egg production on low (12.5%), medium (14.5%) or high (16.5%) protein levels. These birds were equally divided between laying batteries and laying houses. The following information was derived from these tests.

(1) A level of 12.5% of protein was too low for satisfactory production of eggs. This group was inferior in egg production, egg weight, average body weight, days to first egg, and feed consumption to those on each of the higher levels of protein.

(2) A level of 16.5% of protein was superior to one of 14.5% only in egg size and days to first egg. Feed efficiency was greater for the group receiving 14.5% protein, and production at this level was the most economical of that at any level.

(3) Animal protein supplements gave superior results to vegetable protein even though the latter was supplemented by 2.5% of powdered buttermilk. The differences were small, however, except in the case of sexual maturity as measured by days to first egg, in which a difference of 10 days was recorded in favour of the animal protein mixture. In economy of production and in hatchability the animal protein supplement was also superior to a moderate degree.

(4) Pullets which were kept in the cages of a laying battery were very much superior in all respects to those which were kept in laying pens. The degree of superiority is evidenced by the difference of approximately 26 eggs per bird. As the pullets used were moderately late hatched for the area (May 15) it does not follow that so great a difference should necessarily be expected with early hatched birds which would normally be in production before the onset of very cold weather.

(5) Mortality was similar for all treatments with the exception of the high protein level where a death rate significantly higher than that of the medium and low protein groups was experienced.

On the basis of the results reported herein and of those of the rearing phase of this experiment previously reported, it is concluded that a very low protein level, viz., 12.5% is too low for satisfactory rearing of pullets and for subsequent egg production. A level of 14.5% of protein, on the other hand, may be expected to give very similar growth, and greater efficiency in rearing at a lower cost than a level of 17%, and equally as satisfactory results as those from a 16.5% level during the period of egg production following.

Also, for both growth and egg production, a mixture of the common animal protein supplements—fish meal, meat meal and buttermilk powder—may be expected to give superior results to one made up of soy bean meal with a small percentage (2.5%) of buttermilk powder. Since the superiority of the former is consistent but relatively small in actual degree, the use of the latter is indicated in times of scarcity or when price levels favour the vegetable protein source to a marked degree.

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ERRATUM

In the December 1943 issue of *Scientific Agriculture* (Vol. 24, No. 4), the Book Review "The Parasite Catalogue of The Imperial Parasite Service," Page 199, Part 1, should read:—

Part 1, listing about 1,000 species of Arachnida and Coleoptera and about 1,300 species of parasites (pp. ix and 151) and Part 2, listing about 600 species of Dermaptera and Diptera, are now ready.